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Water Management

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The Montana Irrigator's Pocket Guide

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WATER MANAGEMENT

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WATER MANAGEMENT

INTRODUCTION

The Montana Irrigators' Pocket Guide is a take-to-the-field aid to help irrigators save energy and water. The Water Management section describes procedures for assessing soil texture and other variables that influence soil moisture. The result should be better use of stored soil water and precipitation, better timing of irrigation, and more accurate water application.

Procedures included are easily used for commonly irrigated Montana crops. More complex methods may be needed in certain situations, and these are mentioned in the appropriate sections.

The Pocket Guide is not intended to explain the interactions of soil, water, and crops, which form the basis for procedures described in the guide. Those who want more detail can obtain the publications listed in the bibliography, most of which are available free from the Soil Conservation Service and the Cooperative Extension Service. Blank forms are included at the end of this section to make record keeping easier.

SOIL MOISTURE DEFINITIONS

Irrigators should be familiar with soil moisture definitions because effective irrigation depends on the ability to recognize the different levels of soil moisture. The important definitions are described as follows.

SATURATION

As water is added to dry soil, it displaces air in the pore spaces, eventually filling the spaces. A soil is saturated when its pores are filled, and additional water runs off the surface or drains below the root zone.

FIELD CAPACITY

Field capacity is the amount of water remaining in soil after all free water from irrigation or rain has stopped moving downward in response to gravity. Free water drainage after irrigation takes 12 to 24 hours on sandy soils and around 48 hours on clay soils.

PERMANENT WILTING POINT

When soil moisture is depleted to a certain level, plants wilt because they cannot obtain enough moisture. This is called the "permanent wilting point." Plants will show signs of wilting and drought stress before they reach the permanent wilting point.

AVAILABLE WATER-HOLDING CAPACITY (AWC)

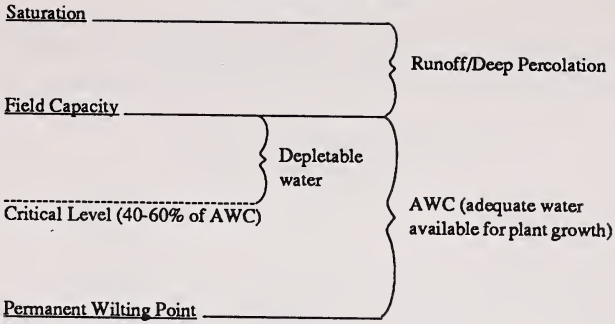
AWC is the amount of water available to plants that a soil can hold (the difference between soil moisture at field capacity and permanent wilting point).

CRITICAL LEVEL

The critical level is the level to which soil moisture can be depleted without stressing plants (generally, 40 to 60 percent of the available water-holding capacity). Once this level is reached, irrigation water should be added.

DEPLETABLE WATER

Depletable water is the amount of soil moisture that can be depleted before the critical level is reached.



Adapted from Montana Irrigation Manual, USDA Soil Conservation Service, Bozeman, MT.

PATH TO IRRIGATION SCHEDULING

- Determine Available Water-holding Capacity (AWC)
- Calculate Critical Level
- Calculate Depletable Water
- Estimate Crop Water Use and Irrigation Date
- Determine Soil Water Content and Schedule Irrigations
- Determine Application Time and Irrigate

DETERMINING AWC

At the beginning of each growing season, follow six steps to calculate AWC. Detailed instructions for each step are found on the pages noted.

Step 1. Sample soil—page 4.
NOTE: The SCS has mapped and classified over 675 soil types in Montana. Included in the descriptions are texture, available

water-holding capacity, depth to water table, erosion resistance, intake characteristics, and other soil qualities. The soil map for a particular piece of property can be obtained by supplying the SCS with the property's legal description. Because of variations in a field, however, a "feel" test also should be done.

Step 2. Identify and jot down the texture and depth of each layer—page 5.

Step 3. Estimate the AWC for each soil texture—page 9.

Step 4. Increase or decrease the estimated AWC if the soil is heavily influenced by certain conditions—page 10.

Step 5. Determine the root depth at various post-emergence dates—page 10.

Step 6. Calculate AWC based on the previous steps—page 11.

NOTE: Spring grain growing on soil consisting of four textural layers will be used as an example to illustrate these steps.

Step 1. Soil Texture Sampling

A soil's AWC depends primarily on soil texture, which can be determined by a "feel" test.

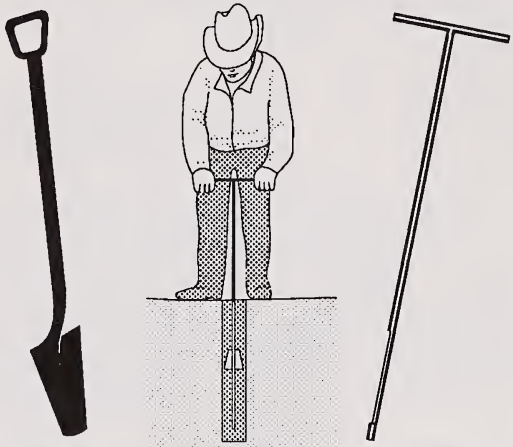
Equipment: Soil sampling tool
Small clean bucket
Bottle of water with drip spout

Take soil samples up to 5 feet deep from each quarter section at six to ten representative locations, or sample each 20 acres.

Soil Sampling Tools

Soil sampling is a necessary part of efficient water use—first to determine soil texture, and second to track soil moisture. Tools for sampling are shown in the following figure.

Soil Sampling Equipment



Tile spade | Bucket auger | Open side sampling tube

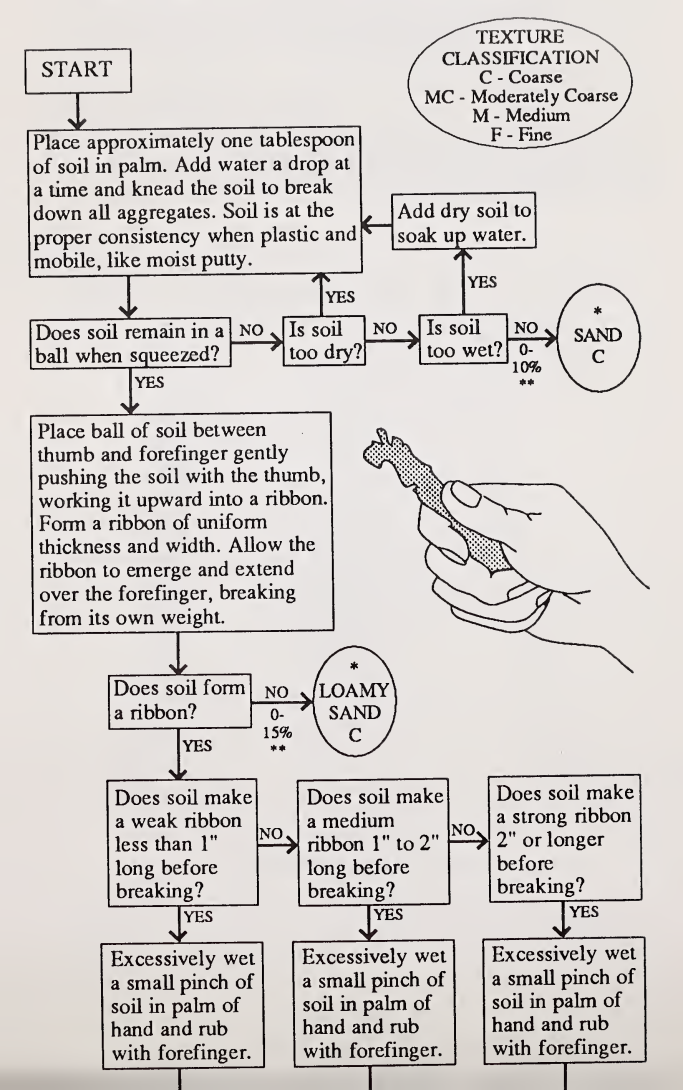
Adapted from Montana Irrigation Manual, USDA Soil Conservation Service, Bozeman, MT

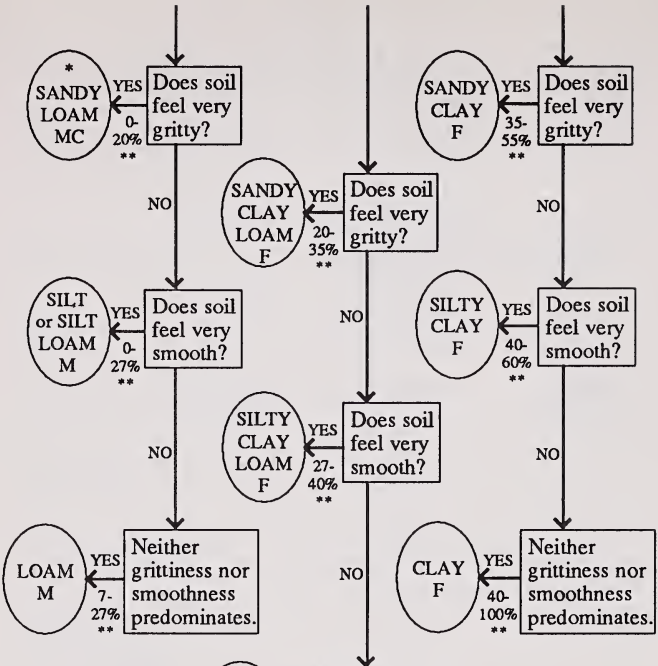
During a soil test, note other factors that influence crop growth such as a high water table, fluctuating water table, hardpans, compacted layers, mineral layers, root penetration, and tilth and condition of the soil.

Step 2. Identify and jot down soil texture.

Use the following chart to identify the soil texture. Refer to the example on page 8.

Determining Soil Texture by the "Feel" Method





* Sand particle size should be estimated (very fine, fine, medium, coarse) for these textures. Individual grains of very fine sand are not visible without magnification and there is a gritty feeling to a very small sample ground between teeth. Some fine sand particles may be just visible. Medium sand particles are easily visible. Examples of sand size descriptions where one size is predominant, are: very fine sand, fine sandy loam, loamy coarse sand.

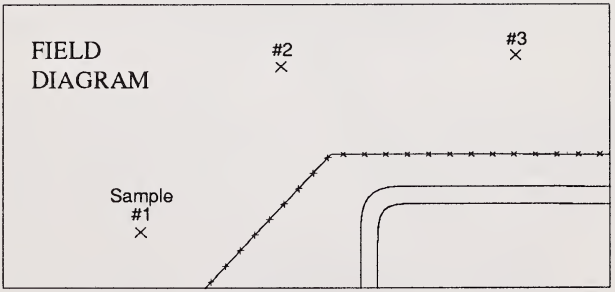
** Clay percentage range.

Adapted from Montana Irrigation Manual, USDA Soil Conservation Service, Bozeman, MT.

Example: **SOIL TEXTURE SAMPLES**

Date 3/88 **Field #** Lower 40 **# Acres** 40

1. Probe each quarter section at six to ten representative locations, or probe each 20 acres. Unusual areas in the field such as wet spots, saline seeps, and rocky areas should be avoided or recorded separately.
2. Record on field diagram where samples were taken.
3. Note other factors such as high water table, hardpan, compacted layers, mineral layers, root penetration, tilth, and condition of the soil.



	Accumulated Soil Layer Depth	Soil Texture Class	Series Name (if known)
Sample # 1	0 to 1 ft.	Silt Loam	Bozeman
	1 to 2 ft.	Silty Clay Loam	
	2 to 3-1/2 ft.	Silt Loam	
	3-1/2 to 5 ft.	Silty Clay Loam	
Sample # 2	0 to 1 ft.	Silt Loam	Bozeman
	1 to 2 ft.	Silty Clay Loam	
	2 to 3-1/2 ft.	Silt Loam	
	3-1/2 to 5 ft.	Silty Clay Loam	
Sample # 3	0 to 1 ft.	Silt Loam	Bozeman
	1 to 2 ft.	Silty Clay Loam	
	2 to 3-1/2 ft.	Silt Loam	
	3-1/2 to 5 ft.	Silty Clay Loam	

Step 3. Estimate AWC by Soil Texture.

From the following table, estimate inches of AWC per foot of soil according to its texture, and jot it down (see the chart on page 11). Generally, clay soils can hold more water than sandy soils.

Soil AWC (Rough Estimate)

Soil Texture	Inches Water per Foot of Soil (range)	(typical)
Coarse Sand	0.1 - 1.2	0.5
Sand	0.1 - 1.4	0.5
Fine Sand	0.5 - 1.4	1.25
Very fine sand	0.7 - 1.4	1.25
Loamy coarse sand	0.5 - 1.7	1.0
Loamy sand	0.5 - 1.7	1.0
Loamy fine sand	0.7 - 2.2	1.25
Loamy very fine sand	0.7 - 2.2	1.25
Coarse sandy loam	0.7 - 1.9	1.25
Sandy loam	1.0 - 2.2	1.5
Fine sandy loam	1.2 - 2.2	1.5
Very fine sandy loam	1.4 - 2.6	2.0
Loam	1.4 - 2.6	2.0
Silt loam	1.4 - 2.9	2.0
Silt	1.4 - 2.6	2.0
Sandy clay loam	1.4 - 2.6	2.2
Clay loam	1.4 - 2.9	2.2
Silty clay loam	1.4 - 2.9	2.2
Sandy clay	1.2 - 2.9	2.0
Silty clay	1.2 - 2.6	2.0
Clay	1.4 - 2.6	2.0

Adapted from Montana Irrigation Manual, USDA Soil Conservation Service, Bozeman, MT.

Step 4. Estimate Factors That Increase or Decrease AWC.

AWC can vary widely between soil types, within the same soil type, and from year to year. Conditions that influence this variation are shown below. The local Conservation District office can help determine the percentage that these conditions increase or decrease the AWC of the soil.

- o Density
- o Compaction
- o Tilth
- o Soil Structure
- o Organic Matter
- o Vegetative Cover
- o Restrictive Layers
- o Depth
- o Rocks
- o Salts/Sodium

Once the percentage is known, increase or decrease the AWC by this amount (see example calculations in the chart on page 11).

Step 5. Determine Root Depth.

AWC is calculated to the depth from which a plant extracts water. The root depth varies by crop, its stage of growth, and growing conditions. Column 2 of the CROP DATA chart beginning on page 13 shows the depth of unrestricted root zones for normally irrigated Montana crops at different growth stages.

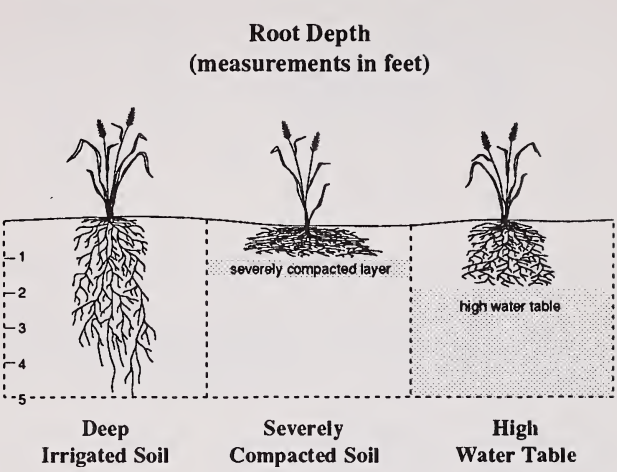
The following table is more precise, based on days of post-emergence. The root depth averages may vary depending on soil, crop, and climate.

Average Root Depth for Irrigated Crops During the Cropping Season

Days Post-Emergence	Average Rooting Depth
0 - 10	1 foot
10 - 30	2 feet
30 - 50	3 feet
50 - 90	4 feet
90+	5 feet

Adapted from Scheduling Irrigation with Evaporation Pans, Cooperative Extension Service, Montana State University, Bozeman, MT.

Growing conditions restricting root depths include dry or severely compacted soil, a high water table, and rock.



Adapted from Montana Irrigation Manual, USDA Soil Conservation Service, Bozeman, MT.

Step 6. Calculate total AWC.

a) First, chart the information gathered in steps 1 through 4.

(a)

Layer Thickness	Soil Texture	AWC (inches per foot)		Adjust for Factors*		Net AWC (inches/foot)
1 foot	silt loam	2.0	x	85%	=	1.7
1 foot	silty clay loam	2.2	x	85%	=	1.9
1 1/2 feet	silt loam	2.0	x	85%	=	1.7
1 1/2 feet	silty clay loam	2.2	x	85%	=	1.9

*Assume soil salinity decreases AWC by 15%.

b) Next, chart the root zone information gathered from step 5.

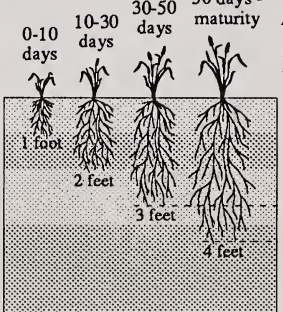
c) Then, for each soil texture layer in the root zone, multiply the layer thickness (in feet) by its net AWC value. Add the resulting values to arrive at total AWC for the root zone.

Post-Emergence	(b) Root Depth	(c) AWC Per Root Depth
0-10 days	1 foot	1 ft. x 1.7 in./ft. AWC = 1.7 in. (layer 1)
10-30 days:	2 feet	1 ft. x 1.7 in./ft. AWC = 1.7 in. (layer 1) 1 ft. x 1.9 in./ft. AWC = 1.9 in. (layer 2) **total AWC = 3.6 in.**
30-50 days:	3 feet	1 ft. x 1.7 in./ft. AWC = 1.7 in. (layer 1) 1 ft. x 1.9 in./ft. AWC = 1.9 in. (layer 2) 1 ft. x 1.7 in./ft. AWC = 1.7 in. (layer 3) **total AWC = 5.3 in**
50 days to maturity:	4 feet*	1 ft. x 1.7 in./ft. AWC = 1.70 in. (layer 1) 1 ft. x 1.9 in./ft. AWC = 1.90 in. (layer 2) 1.5 ft. x 1.7 in./ft. AWC = 2.55 in. (layer 3) 0.5 ft. x 1.9 in./ft. AWC = 0.95 in. (layer 4) **total AWC = 7.10 in.**

*The Average Root Depth table on page 10 shows growth stages of 1, 2, 3, 4, and 5 feet. However, page 17 shows a maximum root depth of 4 feet for spring wheat, which is the example being used.

The following chart represents these calculations graphically.

Soil Texture		AWC	AWC/ Root Depth
silt loam	1 foot	1.7	1.7
silty clay loam	1 foot	1.9	3.6
silt loam	1½ feet	1.7	5.3
		0.85	
		0.95	7.1
silty clay loam	2½ feet		



CROP DATA

Stage of Growth	Depth of Unrestricted Root Zone	AWC Depleted at Critical Level	Critical Growth Stage	Symptoms of Moisture Stress	General Guides
ALFALFA					
Veg stage first 35 days of new stand	0.5 - 1.0 ft.	60%	Seedling and immediately after cutting	Dull, bluish-green color, then wilting	Irrigate just prior to cutting. Avoid over-irrigation. Deep irrigation to root zone should be done in spring and fall where precipitation is not adequate. Normally, 3 to 4 inches of water are needed between cuttings.
Veg stage 35-90 days of new stand	1.0 - 1.5 ft.	50%			
Veg stage 90 days to dormancy	1.5 - 3.0 ft.	50%			
Established stands	5.0 - 10.0 ft.	50%			
ALFALFA-GRASS					
Veg stage first 35 days of new stand	0.5 - 1.0 ft.	50%	Seedling and immediately after cutting	Dull, bluish-green color, then wilting and firing of leaves	Same as alfalfa. Keep soil moist in upper 4 feet.
Veg stage 35-90 days of new stand	1.0 - 1.5 ft.	50%			
Veg stage 90 days to dormancy	1.5 - 3.0 ft.	50%			
Established stands	3.0 - 6.0 ft.	50%			

Stage of Growth	Depth of Unrestricted Root Zone	AWC Depleted at Critical Level	Critical Growth Stage	Symptoms of Moisture Stress	General Guides
ALFALFA SEED					
Established Stands		60-70%	Beginning of growth to start of flowering	Darkened, bluish-green then wilting of leaves	Spring moisture should be low to favor slow top growth and carrier maturity. Irrigate deep to further root zone just prior to budding. When reproductive stage begins, moisture should be kept at high level until seed is well mature. Late fall watering is not recommended.
Bud stage	5 ft. plus	50%			
Veg stage 90 days to dormancy		50%			
BEANS, DRY					
Veg stage first 35 days	0.0 - 2.0 ft.	40%	Early bloom, pod formation	Dull color, then wilting	Very sensitive to over-irrigation. Last irrigation at time of first set pod maturity.
Reproductive stage	1.5 - 2.5 ft.	40%			
Maturity	3.0 - 4.0 ft.	40%			

Stage of Growth	Depth of Unrestricted Root Zone	AWC Depleted at Critical Level	Critical Growth Stage	Symptoms of Moisture Stress	General Guides
CORN, FIELD					
Veg stage first 35 days	1.0 - 2.0 ft.	50%	Tasseling, silk stage until grain becomes firm	Dull green color, leaf curling or rolling by mid-morning, then wilting	Sensitive to over-irrigation. Needs adequate moisture from germination to dent stage. Restricted moisture shortly after emergence encourages tillering. Moisture shortage after hard dough stage does not affect yield.
Reproductive stage	2.5 - 3.5 ft.	50%			
Maturity	4.0 - 5.0 ft.	50%			
CORN, SWEET					
Veg stage first 35 days	1.0 - 2.0 ft.	50%	Same as field corn	Same as field corn	Same as field corn
Reproductive stage	2.5 - 3.5 ft.	40%			
ORCHARD WITH COVER					
Established Trees		50% at 2-foot level. First irrigation should fill entire root zone.	Prior to flowering and bud development through harvest of fruit	Leaf color dulls, shoots droop. Blossoms drop. Fruit growth decreases. Fruit drops prematurely.	Some fruits are sensitive to stress during last two weeks to harvest.
Apple	5+ ft.				
Cherry	6 - 9 ft.				

Stage of Growth	Depth of Unrestricted Root Zone	AWC Depleted at Critical Level	Critical Growth Stage	Symptoms of Moisture Stress	General Guides
PASTURE GRASSES					
Veg stage first 35 days	0.0 - 0.5 ft.	50%	First 90 days of establishment	Dark green then wilting	During establishment 50 percent of AWC must be maintained in the root zone. Use light, frequent irrigations.
Reproductive stage	0.5 - 1.5 ft.	50%			
Maturity	1.5 - 3.0 ft.	50%			
Established stand	1.5 - 4.0 ft.	50%			
POTATOES					
Veg stage first 35 days	0.0 - 2.0 ft.	35% at seed depth	Flowering, tuber set to harvest	Darkening of leaves, then wilting	Very sensitive to over-irrigation. Water should not stand around tubers. Light, frequent irrigation best. Lower tuber quality if plants go into serious moisture stress. Last irrigation 3-4 weeks before harvest.
Reproductive stage	1.5 - 3.0 ft.	35%			
Maturity	3.0 - 4.0 ft.	50%			

Stage of Growth	Depth of Unrestricted Root Zone	AWC Depleted at Critical Level	Critical Growth Stage	Symptoms of Moisture Stress	General Guides
SPRING GRAIN					
Veg stage first 35 days	1.0 - 3.0 ft.	60%	Boot, bloom, and early heading. Malting barley: jointing, booting, heading, and soft dough	Dull, dark green color, leaf curling, then firing of lower leaves	Restrict moisture early in year to encourage stooling prior to boot stage. Irrigate to field capacity. Last irrigation at milk to dough stage. Irrigating after late dough stage may decrease grain yield. Small grain as a nurse crop: irrigate for needs, or as for grass or alfalfa seedlings.
Reproductive stage	2.0 - 3.0 ft.	40%			
Maturity	3.0 - 4.0 ft.	60%			
SUGAR BEETS					
Veg stage first 35 days	0.0 - 2.0 ft.	50%	From seeding through root enlargement, (post thinning)	Darkening of leaf,then wilting during mid-day. During hot periods, wilting may occur even when soil moisture is adequate.	Irrigate frequently and lightly during early season to ensure germination and seedling growth. Later in season, avoid irrigating simply because crop shows signs of mid-afternoon wilt.
Veg stage mid-May to mid-September	2.5 - 3.5 ft.	50%			
Maturity mid-August to harvest	4.0 - 6.0 ft.	50%			

DETERMINING CRITICAL LEVEL

The critical level of soil moisture depends on the crop and its growth stage. Different crops will tolerate different soil moisture depletion levels, and most crops are especially sensitive to insufficient water during a certain growth stage. Moisture stress during this stage causes an irreversible loss of yield.

The CROP DATA chart beginning on page 13 shows the percentage of AWC depleted at the critical level for various growth stages for commonly irrigated Montana crops. The chart specifies how moisture stress at the various growth stages can affect crop yield.

DETERMINING DEPLETABLE WATER

Follow these steps to determine depletable water for a crop's growth stage, and root depth during growth stages.

1. From earlier calculations (page 10), note post-emergence root depth.
2. Match post-emergence root depth with the stage of growth shown in column 1 on pages 13-17.
3. From earlier calculations (page 12), enter total AWC for post-emergence root depths.
4. Enter the critical level percentage for the growth stage from column 3 on pages 13-17.
5. Multiply the AWC by the critical level percentage to calculate depletable water.

Step 1		Step 2	Step 3	Step 4	Step 5
Days Post-Emergence	Root Depth	Stage of Growth	AWC per Root Depth	Critical Level	Depletable Amount per Root Depth
0 - 10 days	1 ft.	Vegetative	1.7 in.	60%	1.02 in.
10 - 30 days	2 ft.		3.6 in.	60%	2.16 in.
30 - 35 days	3 ft.		5.3 in.	60%	3.18 in.
35 - 50 days	3 ft.	Repro-	5.3 in.	40%	2.12 in.
50 - * days	4 ft.	ductive	7.1 in.	40%	2.84 in.
* - harvest	4 ft.	Maturity	7.1 in.	60%	4.26 in.

* depends on climate and crop

ESTIMATING CROP WATER USE AND IRRIGATION DATE

Irrigation should be done before the crop's water use reduces the soil moisture below the critical level, and always before the period of peak crop use. A crop's water use depends on the weather, length of growing season, elevation, crop, stage of growth, and the soil's AWC. Some methods used to track these variables are discussed below.

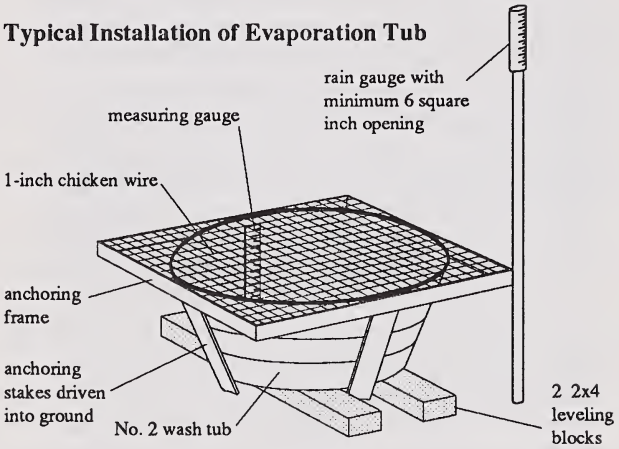
Evaporation Pan

The evaporation pan, or washtub method, for determining crop water use has been used successfully in Montana.

Equipment

- o No. 1 or No. 2 round washtub (20 inches in diameter/10 inches deep)
- o 1-inch chicken wire (to keep animals out)
- o Anchoring frame
- o Measuring gauge (yardstick, ruler, or meter stick)
- o Rain gauge with minimum opening of 6 square inches

Typical Installation of Evaporation Tub



Adapted from Scheduling Irrigation with Evaporation Pans, Cooperative Extension Service, Montana State University, Bozeman, MT.

Procedure

1. Install a tub and rain gauge in the irrigated field, or in a nearby grassy area (see the illustration). Don't place on bare ground, next to gravel or blacktop road, near buildings or under trees. Plants within a 30-foot radius should be mowed but not sprayed with herbicide.
2. When the soil is at field capacity (either by rain or irrigation), fill tub with 8 inches of water.
   NOTE: Water depth in the tub should be kept between 5 and 8 inches. Place marks on the inside of the tub to show minimum and maximum depths. If water depth in the tub falls below 5 inches, refill to 8 inches. If rainfall causes the water level in the pan to rise above the 8-inch mark, pour out the excess water. Water in excess of field capacity, as represented by the 8-inch level, cannot be held by the soil and percolates out the bottom of the root zone.
3. Add 1/10 inch of water to rain gauge and a 4/10 inch layer of mineral oil to prevent evaporation.
4. Record the amount of water in the pan and rain gauge daily or every few days. Total evaporation equals 75 percent of total rainfall over 1/10 of an inch, plus the amount of water evaporated from the tub.
5. At irrigation time, refill tub to 8-inch depth, and dump water out of rain gauge and replenish with water and mineral oil.

Steps to Estimate Crop Water Use Based on Evaporation Pan

1. Every few days measure the amount of water evaporated from the tub.
   NOTE: Measure the tub water at the same spot so differences in the tub's bottom shape won't mislead readings. A mark placed inside on the tub's bottom helps.
2. Check the rain gauge reading. Calculate 75 percent of total rainfall if over 1/10 of an inch.

3. Add net rainfall amount to the amount of water gone from the tub.

4. Calculate average daily water use by dividing the total amount of evaporation by the number of days between readings.

5. Adjust for pan location. When the irrigated fields are small, or the field and tub are surrounded by dryland or fallow fields, wind will cause greater evaporation from the pan than the crop is extracting from the soil. To compensate, multiply the daily pan evaporation amount by the Montana pan coefficient of 65 percent. In areas where large acreages are being irrigated and the pan can be placed in the middle of the irrigated acreage, adjustment is not necessary.

6. Jot down the percentage shown in the Crop Growth Stage Adjustment table on pages 24 and 25. Crop water use during the early part of the season will be somewhat less than evaporation from the pan. At mid-season, crop water use may be approximately the same as evaporation from the pan, or greater. As the crop approaches maturity, its water use rate decreases.

7. To calculate the average net daily crop water use, multiply the pan water loss by the the crop growth stage percentage.

8. Find the soil water used for the period by totaling average net crop water use and deducting effective rainfall from the result.

9. Subtract the soil water used from the maximum depletable amount to find depletable water remaining.

10. Estimate the irrigation date. Divide depletable water remaining by the average net daily crop water use. When calculations show the soil water is approaching maximum depletion, it's time to irrigate.

Example: Use soil and spring grain examples from page 12. Assume the crop is growing on a small irrigated field surrounded by dryland and fallow areas.

Crop:	Spring wheat
Planting date:	May 1
Emergence date:	May 8
Present date:	June 7, 8:00 a.m.
Days post emergence:	30
Root zone:	2 feet
Net AWC (page 12):	3.6
Critical level (page 17):	60%
Depletable water (page 18):	60% x 3.6 = 2.16 inches

Step 1. Measure tub evaporation:

Beginning pan water level = 8.0 in.
Current pan water level = 7.0 in.
8.0 in. - 7.0 in. = 1.0 in. net tub loss

Step 2. Calculate 75 percent of rainfall since it is over 1/10 of an inch:

Rainfall between readings = 0.44 in.
0.75 x 0.44 = 0.33

Step 3. Add net rainfall to the net tub loss to get evaporation loss:

1.0 + 0.33 in. = 1.33

Step 4. Calculate average daily water loss from pan:

Days between readings = 6

$$\frac{1.33 \text{ in.}}{6 \text{ days}} = 0.22 \text{ in./day}$$

Step 5. Apply pan coefficient of 65 percent to the daily water loss:

0.22 x 0.65 = 0.14 in./day

Step 6. Note adjustments for crop growth stage (interpolate from table on pages 24 and 25).

3 1/2 weeks (June 1 - 4)	=	0.75
4 weeks (June 5 - 7)	=	0.83

Step 7. Calculate average net daily crop water use:

June 1 - 4 = 0.14 x 0.75	=	0.11 in.
June 5 - 6 = 0.14 x 0.83	=	0.12 in.

Step 8. Calculate total soil water used:

0.11 in./day x 4 days	=	0.44
0.12 in./day x 2 days	=	0.24
	=	0.68
Less net rainfall	=	-.33
	=	0.35

Step 9. Calculate remaining depletable water:

Maximum depletable water	=	2.16 in.
Less soil water used	=	0.35 in.
Remaining depletable water	=	1.81 in.

Step 10. Estimate irrigation date:

$$\frac{1.81}{0.12 \text{ in./day}} = 15 \text{ days}$$

In this example, the 15 day estimate may be too long because in the next few weeks the crop's daily water use will increase due to its growth stage (as reflected by the crop growth stage percentages in the table on page 24), and due to warmer weather. Therefore, the irrigation date (if it doesn't rain) will be sooner than June 22. Monitoring the pan's evaporation will track the change. When the cumulative soil water used approaches the maximum depletable water, it's time to check soil moisture and schedule irrigation.

The chart on page 26-27 shows the readings and calculations from an evaporation pan.

Evaporation Pan
Crop Growth Stage Adjustments
(Decimal Equivalents of Percentages)

Weeks After Emergence	Alfalfa	Barley	Beans	Corn	Pasture Grasses	Potato	Spring Grain	Sugar Beets	Sun-flowers	Winter Wheat
1	0.70	0.15	0.16	0.22	0.68	0.32	0.26	0.26	0.50	0.56
2	0.86	0.34	0.29	0.30	0.80	0.46	0.48	0.32	0.68	0.68
3	0.96	0.49	0.44	0.40	0.90	0.61	0.66	0.42	0.80	0.80
4	1.04	0.64	0.58	0.52	0.96	0.74	0.83	0.56	0.92	0.92
5	1.08	0.77/tillering	0.72	0.66	1.00	0.85	0.95	0.67	1.00	0.98
6	1.10	0.89	0.84	0.80	1.04	0.92	1.02	0.78	1.06	1.04
7	1.10	0.98/boot	0.92	0.91	1.04	0.99	1.06	0.88	1.10	1.06
8	1.10	1.05/heading	1.00	0.98	1.04	1.04	1.05	0.95	1.08	1.06
9	1.10	1.06	1.06	1.06	1.04	1.06	1.00	1.01	1.06	0.96
10	1.10	1.05/anthesis	1.10	1.10	1.04	1.04	0.92	1.06	1.02	0.83
11	1.10	1.02/early milk	1.10	1.10	1.04	0.98	0.81	1.09	0.95	0.56
12	1.10	0.98	1.08	1.08	1.04	0.92	0.68	1.10	0.88	0.20
13	1.10	0.92/soft dough	1.00	1.04	1.04	0.84	0.56	1.10	0.78	
14	1.10	0.85	0.90	0.96	1.04	0.75	0.40	1.08	0.66	
15	1.10	0.78/hard dough	0.76	0.86	1.04	0.66	0.24	1.07		

Weeks After Emergence	Alfalfa	Barley	Beans	Corn	Pasture Grasses	Potato	Spring Grain	Sugar Beets	Sun-flowers	Winter Wheat
16	1.10	0.69	0.56	0.74	1.04	0.58		1.04		
17	1.10	0.59	0.38	0.56	1.04	0.46		1.00		
18	1.10				1.04			0.95		
19	1.09				1.04			0.90		
20	1.08				1.02			0.85		
21	1.04				0.96					
22	1.02				0.88					
23	0.94				0.80					

Adapted from Scheduling Irrigation with Evaporation Pans. Montana State University. Cooperative Extension Service.

EVAPORATION PAN

Worksheet for Determining Remaining Depletable Soil Water and Approximate Daily Water Use Rates

OBSERVER G. Irrigator

LOCATION Bozeman

CROP Spring Wheat

PLANTING DATE 5/1

EMERGENCE DATE 5/8

SOIL Bozeman Silt Loam

INTAKE RATE 3.0 inches/hour

IRRIGATION APPLICATION (Sprinkler only) N/A

MAXIMUM ROOTING DEPTH 4 feet

Month/ Day	Days/Week Post-Emergence	Time	Step 1: Pan Water Level (inches)	Step 1: Change in Pan Water Level (inches)	Step 2: Rain Gauge Reading x 0.75 (inches)	Step 3: Total Evap. = Pan Loss Plus Effective Rainfall (inches)	Step 4: Average Daily Crop Water Use (inches)	Step 5: Adjust for Location = Daily Use x 0.65 (inches)	Step 6: Crop Growth Stage Adjustment
6/1	24/3 1/2	8 AM	8.00				1.33/6=0.22	0.14	0.75
6/2	25						0.22	0.14	"
6/3	26						0.22	0.14	"
6/4	27						0.22	0.14	"
6/5	28/4						0.22	0.14	0.83
6/6	29						0.22	0.14	"
6/7	30	8 AM	7.00	1.00	.44/.33	1.00+0.33=1.33	1.42/5=0.28	0.19	"
6/8	31/4 1/2						0.28	0.19	0.89
6/9	32						0.28	0.19	"
6/10	33						0.28	0.19	"
6/11	34						0.28	0.19	"
6/12	35/5	8 AM	5.58	1.42	0	1.42+ 0 = 1.42	0.56/3=0.19	0.12	0.95
6/13	36						0.19	0.12	"
6/14	37						0.19	0.12	"
6/15	38/5 1/2	8 AM	5.34	0.24	.43/.32	0.24+0.32= .56			0.99

Step 7	Step 8	Step 9		Step 10	
Average Net Daily Crop Water Use (inches)	Accumulated Soil Water Use (inches)	Maximum Depletable Water (inches)	Remaining Depletable Water (inches)	Estimate Irrigation Date	NOTES
0.11		2.16			Irr 5/31. Fill pan to 8 in.
0.11		"			
0.11		"			
0.11		"			
0.12		"			
0.12	0.68-0.33=0.35	"	2.16-0.35=1.81	1.81/0.12=15 days	Emptied rain gauge
0.16		"			
0.17		3.18			Adjust depletable water to 3 ft root
0.17		"			
0.17		"			
0.17	1.19	"	3.18-1.19=1.99	1.99/0.17=11 days	
0.12		2.12			Adjust to 40% depletable amount
0.12		"			
0.12	1.55-0.32=1.23	"	2.12-1.23=0.89	0.89/0.12= 7 days	Emptied rain gauge Est. irr 6/20
		"			Test soil moist. on 6/17

For irrigated cover crops such as pasture, and alfalfa, alfalfa/grass, and grass hay, the evaporation pan method can be simplified.

1. Set up the evaporation tub in the field being irrigated according to the diagram on page 19. Set the tub at least 100 feet inside the field boundaries. Clip any vegetation overhanging the tub.
2. Mark a line 8 inches from the tub bottom. Drill a small (1/4 inch) hole. The drilled hole will prevent rain from pushing the water above the 8-inch level.
3. Calculate the maximum depletable water (page 18). Subtract this value from 8 inches.
4. On the tub's inside, mark a second line showing the water level when the depletable amount has evaporated. For example, if the maximum depletable water is 2.16 inches, mark a line at the 5.84 inch level (8 inches - 2.16 inches = 5.84 inches).
5. Check the tub periodically. When the tub's water has evaporated almost to the depletion mark, irrigate the field.
6. Before sprinkler irrigating, plug the hole at the tub's 8-inch level with gum or putty. Watch the tub's water level during irrigation. When the water level reaches 8 inches, the soil's water content has been brought to field capacity and the soil can't hold any more water. If the water rises above 8 inches, you are over-irrigating.

Daily Temperatures

Another method to estimate crop water use is based on daily temperatures acquired from local news media or by reading a maximum-minimum thermometer installed in the field.

Steps to Estimate Crop Water Use Based on Daily Temperatures

1. Calculate the average 24-hour temperature. To do this, add minimum to maximum temperature and divide the result by 2.
   Example: 50° low and 80° high for 24 hours

$$\frac{50+80}{2} = 65° \text{ average temperature}$$

2. Select the appropriate crop table (pages 31-32). Write down the water use rate for the average daily temperature and the crop's growth stage.
   NOTE: Montana State University may develop tables for other crops. When they do, your county extension agent will be able to supply that information.

3. If rainfall exceeds 1/10 of an inch, subtract 75 percent of the measured amount from the cumulative water use.

4. After a few days of record keeping, estimate the approximate water use for the next few days and schedule the next irrigation.

Example: Use the example from page 18.

Crop: Spring grain
Weeks post-emergence: 7 1/2 (reproductive stage)
Depletable water: 40% of 7.1 AWC = 2.84 inches
No rain during the period.

Day	Temperature			Average Daily Use Rate	Cumulative Water Use
	Low	High	Average		
$7^1/_2$ weeks after emergence					
Monday	50	78	64	0.15	0.15
Tuesday	49	97	75	0.21	0.36
Wednesday	55	103	79	0.21	0.57
Thursday	52	100	76	0.21	0.78
8 weeks after emergence					
Friday	52	96	74	0.22	1.00
Saturday	58	102	80	0.26	1.26
Sunday	56	100	78	0.22	1.48
Monday	55	104	80	0.26	1.74
Tuesday	57	103	80	0.26	2.00
Wednesday	50	91	71	0.22	2.22

Assuming temperatures will remain much the same for the next few days, the total water use on Friday would be 2.66 (2.22 + 0.22 + 0.22 = 2.66)—close to the depletable water of 2.86 inches. Hence, a 2 3/4-inch net irrigation should be scheduled that will reach the last set by Friday. For greater accuracy, soil moisture should be tested on Wednesday or Thursday to verify that an irrigation is necessary.

Average Daily Water Use For Typical Montana Irrigated Crops as Affected by Daily Temperature

ALFALFA

	For the first cutting and for the fourth and subsequent weeks after cutting.								For the first three weeks after cutting.								
Month		**May**			**June**	**July**	**Aug.**	**Sep.**	**June**			**July**			**Aug.**		
Week	1	2	3	4	All	All	All	All	1	2	3	1	2	3	1	2	3
Temperature									**(inches/day)**								
50-59	.04	.04	.05	.06	.09	.09	.08	.07	.06	.07	.09	.06	.07	.09	.05	.06	.08
60-69	.04	.07	.09	.11	.15	.15	.13	.10	.10	.12	.14	.10	.12	.12	.09	.10	.12
70-79	.05	.10	.14	.16	.21	.22	.18	.13	.14	.17	.20	.15	.18	.21	.12	.14	.17
80-89	.06	.12	.17	.19	.25	.26	.22	.17	.17	.20	.24	.17	.21	.25	.15	.18	.21
90-99	.08	.14	.19	.23	.29	.30	.26	.20	.19	.23	.28	.20	.24	.29	.17	.21	.25

CORN

Week After Emergence	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Temperature	(inches/day)																
50-59	.04	.04	.04	.04	.05	.07	.08	.09	.09	.09	.09	.09	.09	.08	.08	.06	.05
60-69	.04	.04	.05	.07	.09	.11	.13	.15	.15	.15	.14	.14	.14	.13	.13	.09	.07
70-79	.04	.05	.07	.10	.12	.15	.19	.22	.22	.22	.20	.20	.20	.18	.17	.11	.09
80-89	.04	.06	.08	.12	.15	.18	.23	.25	.26	.26	.24	.24	.24	.22	.21	.14	.12
90-99	.05	.07	.10	.13	.17	.21	.26	.29	.30	.30	.29	.29	.29	.26	.25	.17	.14

WHEAT

Week After Emergence	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Temperature	(inches/day)													
50-59	.04	.04	.04	.06	.08	.08	.09	.08	.08	.08	.08	.07	.06	.05
60-69	.04	.04	.07	.10	.13	.14	.15	.15	.15	.15	.14	.13	.09	.08
70-79	.04	.06	.10	.14	.18	.20	.21	.22	.22	.22	.21	.18	.13	.12
80-89	.04	.07	.12	.17	.21	.24	.25	.26	.26	.26	.24	.22	.16	.14
90-99	.05	.09	.14	.19	.24	.27	.29	.30	.30	.30	.28	.25	.19	.17

Computer Programs

Two computer programs, CONSUMPT and SCHEDULE, do the calculations and record keeping required to track soil water content and schedule irrigation. Either program can be accessed through AGNET or obtained on a floppy disk for the personal computer. The Montana Cooperative Extension Service can provide the details for these programs.

The Bureau of Reclamation has adopted and modified a computer program developed at the USDA Agriculture Research Station in Kimberly, Idaho. Details of this program are available from the Soil Conservation Service or the Bureau of Reclamation.

MEASURING SOIL WATER CONTENT AND SCHEDULING IRRIGATION

To verify that soil moisture has not dropped below the critical level and that irrigation scheduling is on target, soil moisture should be checked periodically. The next few pages tell where, when and how.

Frequency of Soil Moisture Testing

The first soil moisture test should be just before planting or before an established crop begins to grow, to determine stored water available for crop use. The intervals at which moisture measurements are needed thereafter will depend on the stage of crop growth, climatic conditions, and AWC of the soil. The following chart gives some guidelines. The soil texture is determined from the "feel" method described on pages 6 and 7.

Soil Moisture Check Intervals

Soil Texture	Deep-rooted Crops*	Shallow-rooted Crops*
Coarse	3 - 4 days	2 days
Medium	5 - 6 days	2 - 4 days
Fine	8 - 10 days	5 - 6 days

*Sooner in hot weather.

A moisture check of perennial crops at the end of the season will tell if irrigation is needed before the water is shut off or a hard freeze occurs.

Field Location of Soil Moisture Tests

Measure soil moisture at two to three field locations which represent average soil moisture conditions. Avoid excessively moist areas such as low spots in a field or areas around a leaky pipe, and excessively dry areas such as high spots in a field.

For fields with more than one soil texture, set up at least two measurement stations at areas that dry out first. Irrigation frequency or set times can be tailored for different parts of the field.

Soil Moisture Tests Relative to Plants

- o Row crops: as near the plants as possible.
- o Mature trees: 4 to 6 feet from the trunk but inside the tree drip line.
- o Cover crops such as alfalfa and grain: in representative soil and slope areas of the field.

Depth of Soil Moisture Tests

Measure soil moisture at the depths the plant roots extract moisture.

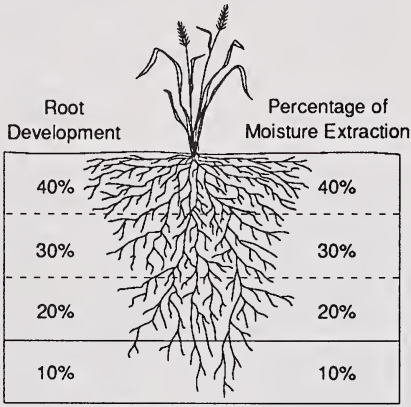
- o For uniform soils and 4-foot or deeper root zones, measure at mid-point in each quarter of the root zone. Thus, a

4-foot-deep root zone would be measured at 6, 18, 30, and 42 inches.

- For root zones 3 feet or less, take three measurements. For example, measure a 24-inch root zone at 6, 12 and 18 inches.
- For soils of different textures, take one measurement in each layer.

Root development tends to be densest near the soil surface, and most water is therefore taken up there, as illustrated in the following figure. About 70 percent of the crop's water requirement is taken from the upper half of the root zone. The crop root depth changes in the early part of the growing season for annual crops (see the CROP DATA chart on pages 13-17).

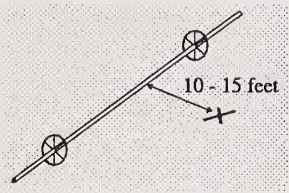
Moisture Extraction Based on Root Distribution



Adapted from Montana Irrigation Manual, USDA Soil Conservation Service, Bozeman, MT.

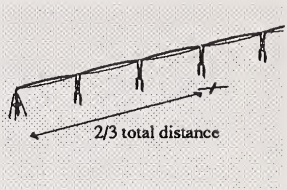
Where to Test Soil Moisture for Different Irrigation Systems

Side Roll/Hand Move



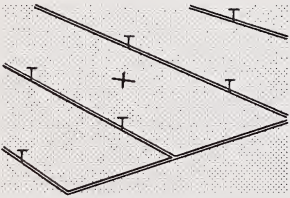
Halfway between adjacent sprinkler heads and 10 to 15 feet from the lateral.

Center Pivot



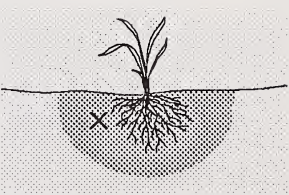
At a point two-thirds of the total lateral distance from the pivot.

Solid Set



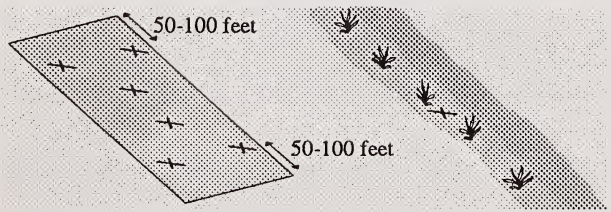
At a point midway among four adjacent sprinkler heads.

Trickle



Within the wetted ball in the root zone.

Graded Border, Contour, Ditch, or Furrow/Corrugation



On both sides of the field: (1) 50 to 100 feet downstream from start of irrigation run, (2) 50 to 100 feet upstream from end of irrigation run, (3) one or two places in the center. For furrow or corrugation place in the center of the bed near plants.

Soil Moisture Testing Based on Feel and Appearance

Use a soil sampling tool to take 6 to 10 walnut-sized soil samples from a field in accordance with the guidelines on pages 38 to 41.

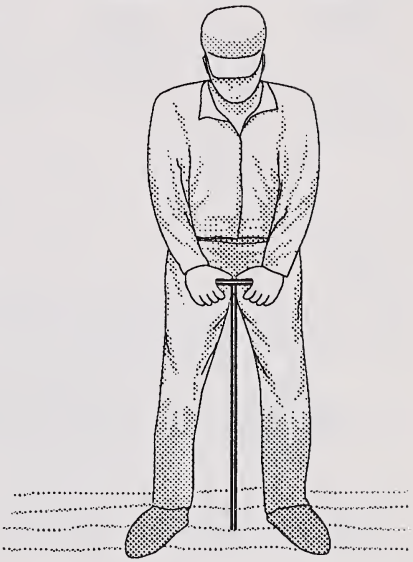
The Paul Brown probe is probably the most widely used tool for taking soil moisture samples, although the tools shown on page 5 also are used. The 4-foot-long Paul Brown probe is made of 1/2-inch steel rod with a 5/8-inch ball bearing and 3/8-inch auger welded on the bottom.

Procedure:

1. Push the probe vigorously into the soil without turning by bearing weight on the handle. (The probe will stop abruptly at dry soil. Rocks and gravel will also stop the probe, but are easily detected by the metallic click.)

Paul Brown Moisture Probe

Using a Paul Brown Probe



2. Extract a small soil sample by turning the probe 2 or 3 clockwise revolutions while applying pressure to the handle, then pull the probe up from the soil without turning.
3. Check the marking on the probe shaft to determine the depth of the soil sample.
4. Determine the feel and appearance class of the samples from the following table.

Checking Soil Moisture with Paul Brown Probe

Determining Soil Water Deficit by Feel and Appearance

Feel and Appearance Class	Depleted Water	Coarse (C)	Moderately Coarse (MC)	Medium (M)	Moderately Fine and Fine (F)
F	Exceeds field capacity	Free water appears when soil is bounced in hand.	Free water is released with kneading.	Free water can be squeezed out.	Puddles and free water forms on surface.
E	At field capacity	Upon squeezing, no free water appears on soil, but wet outline of ball is left on hand.			
D	0 - 25%	Tends to stick together, forms a weak crumbly ball under pressure.	Forms weak ball that breaks easily; does not slick.	Forms a ball and is very pliable; slicks readily if relatively high in clay.	Ribbons out between thumb and finger; has a slick feeling.

C	25 - 50%	Tends to stick together. May form a very weak ball under pressure.	Tends to ball under pressure, but seldom holds together.	Forms a ball, somewhat plastic; slicks slightly under pressure.	Forms a ball; ribbons out between thumb and finger.

For most crops, irrigation should begin prior to 50 percent deficit.

B	50 - 75%	Appears to be dry; does not form a ball under pressure.	Appears to be dry; does not form a ball under pressure.	Somewhat crumbly but holds together under pressure.	Somewhat pliable; balls under pressure.
A	75 - 100%	Dry, loose, single-grained flow through fingers.	Dry, loose, flows through fingers.	Powdery dry, sometimes slightly crusted but easily breaks down into powder.	Hard, baked, cracked; sometimes has loose crumbs on surface.

Depleted water is AWC less the present soil water content. It is the amount of water required to refill the root zone to field capacity and is measured in percentage of AWC or in inches.

Adapted from Montana Irrigation Manual, USDA Soil Conservation Service, Bozeman, MT.

Calculate the soil water deficit for the crop root zone. Assume the crop is mature with a root depth of 4 feet.

Step 1. In the first four columns, chart the information gathered earlier (page 11).

Step 2. Find the critical level. Page 17 shows the critical level for mature spring grain occurs at 60 percent depletion of AWC, or in this case when 4.3 inches of soil moisture have been used.

Step 3. Note depth of soil samples which were taken within each textural layer.

Step 4. Estimate feel and appearance class. Assume that the result is classes A, B, C, D for the different layers.

Step 5. Apply the percentages for these classes to the AWC to find the soil water deficit.

Calculating Soil Water Deficit

Step 1

Layer Thickness	Soil Texture	Net AWC	AWC per layer to root depth
		(inches/foot)	(inches/foot)
1 foot	Silt loam	1.7	1.70
1 foot	Silty clay loam	1.9	1.90
1 1/2 feet	Silt loam	1.7	2.55
1/2 foot	Silty clay loam	1.9	0.95
			7.10

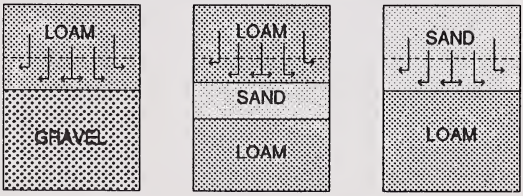
Step 2: Depletable water = 60% x 7.1 = 4.3

Step 3	Step 4	Step 5	
Depth of Soil Sample	**Feel and Appearance Class**	**Soil Water Deficit**	**Soil Water Deficit**
(inches)		**(percent)**	**(inches/foot)**
6	A	90	1.70 x 90% =1.53
18	B	75	1.90 x 75% =1.43
30	C	50	2.55 x 50% =1.28
42	D	25	0.95 x 25% =0.24
		Total soil water deficit = 4.48	

In this example, irrigation has been delayed to where more than 60 percent of the AWC has been used and, consequently, the depletable water has been exceeded. Irrigation should have been started when the soil water deficit approached the depletable water amount.

Changes in soil texture act as a temporary barrier to water movement. Fine soil overlying a coarse soil, or vice versa, must become very wet before water will move down through the subsoil. Under these conditions, the overlying soil holds up to two or three times as much water as it would in more uniform soils.

Water Movement in Stratified Soils



Reprinted from Montana Irrigation Manual, Soil Conservation Service, Bozeman, MT.

Tensiometer

Tensiometers, available in lengths from 6 inches to 5 feet, quickly reveal moisture conditions by measuring soil water tension. However, using tensiometers takes some care. They have to be placed after the last freeze and removed before the first freeze and their location has to be marked so they won't be damaged by field equipment. The initial calibration of tensiometer readings to plant-available water is done once per season. Tensiometers require maintenance during the season. The tensiometer is not suited to soils with high clay content. The SCS or Cooperative Extension Service has information on using tensiometers.

For those who are using tensiometers, the following table provides a quick reference for soil moisture readings. The table must be supplemented with a graph correlating tensiometer readings with different soil moisture levels.

Interpretation of Tensiometer Readings

Moisture Condition	*Dial Reading (Centibars)	Intepretation
Nearly Saturated	0 (sandy) 10 (clay)	Near saturated soil often occurs for a day or two following irrigation. Persistent readings at this level indicates water-logged soils, a high water table, poor soil aeration, or a tensiometer that has broken tension.
Field Capacity	11 (sandy) 20 30 (clay)	In this range, discontinue irrigations to prevent waste by deep percolation and leaching of nutrients below the root zone.

Irrigation Range	40 (sandy) 50 60 (clay)	This is the usual range for starting irrigations. Soil aeration is certain in this range. In general, irrigations start at readings of 30-40 in sandy soils (loamy sands and sandy loams). Irrigations usually start from 40-50 on loamy soils (very fine sandy loams and silt loams). On soils with clay (silty clay loam), irrigations usually start at 50-60. Starting irrigations in this range ensures readily available soil moisture at all times.
Dry	70 (sandy) 80 (clay)	This is the stress range in sandy soils. However, crops are not necessarily damaged or yield reduced. Some soil moisture is available to plants, but it is getting dangerously low for maximum production. Top range of accuracy of tensiometer. Readings above this are possible, but the tensiometer will break tension between 80 and 85 centibars.

*Indicative of soil conditions where the tensiometer is located. Use judgment in correlating these readings to general crop conditions in the field. Sandy soils will have lower tensiometer readings for similar soil moisture levels than will clay-type soils.

Adapted from Montana Irrigation Manual, USDA Soil Conservation Service, Bozeman, MT.

Electrical Resistance Blocks

Electrical resistance blocks are small blocks of nylon, fiberglass, or gypsum with embedded electrodes attached to lead wires. These blocks are placed at various soil depths. Periodically, a portable meter is taken to the field and connected to the

electrical leads to measure the electrical resistance of the blocks, which indicates the soil moisture content. The drier the soil, the greater the electrical resistance.

The blocks work well in any fine-textured (clayey) soil that is neither highly saline nor alkaline. Like the tensiometers, the blocks take some care and need to be calibrated according to soil type. The SCS has information on using various blocks.

For those using the blocks, the following table provides a quick reference for soil moisture readings. The table must be supplemented with a graph correlating resistance readings with different soil moisture levels.

Intepretation of Electrical Resistance Meter Readings

Moisture Condition	Electrical Resistance Ohms	*Meter Readings	Interpretation
Nearly Saturated	less than 200	200 to 180	Near saturated soil often occurs for a day or two following irrigation. Persistent readings at this level indicate water-logged soils, a high water table, or poor soil aeration.
Field Capacity	300 to 500	180 to 170	In this range, discontinue irrigations to prevent waste by deep percolation and leaching of nutrients below the root zone.
Irrigation Range	3200 to 7000	120 to 80	This is the usual range for starting irrigations. Soil aeration is certain in this range. Starting irrigations in this range ensures readily available soil moisture at all times.
Dry	above 7000	less than 80	This is the stress range. However, crops are not necessarily damaged or yield reduced. Some soil moisture is available to plants, but it is getting dangerously low for maximum production.

*Indicative of soil conditions where soil blocks are located. Use judgment in correlating these readings to general crop conditions in the field. Sandy soils will have higher resistance readings for similar soil moisture levels than will clay-type soils.

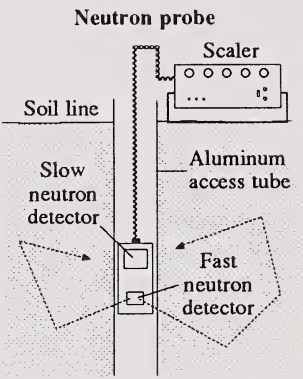
Adapted from Montana Irrigation Manual, USDA Soil Conservation Service, Bozeman, MT.

Neutron Probe

A neutron probe provides fast, accurate measurement of soil moisture. Neutron probe measurements are being offered in several Montana counties through local Conservation Districts. The operator of a neutron probe must be licensed by the Nuclear Regulatory Commission. Because of the probe's cost (around $3500), most irrigators choose to cooperate with other growers to purchase one. The following gives an idea of what is needed to operate these.

Equipment:

- One or two access tubes of aluminum, steel conduit, or polyethylene pipe.
- Water-tight stoppers to plug open end of access tube.
- Neutron moisture probe with microprocessor
- License from USDA and U.S. Nuclear Regulatory Commission to own and operate probe (received after training and passing tests)
- Graph for each site calibrating soil water content with the neutron probe readings.

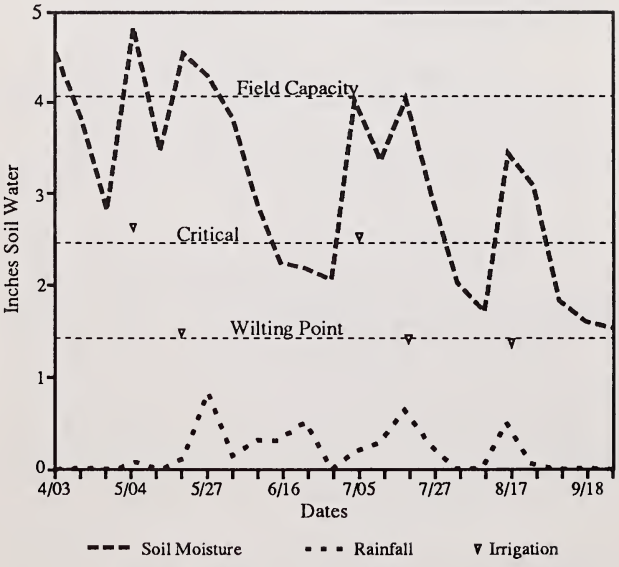


Adapted from Montana Irrigation Manual, USDA Soil Conservation Service, Bozeman, MT.

The access tubes are inserted into the soil at locations in the field where soil moisture will be tracked. At the time of installation, soil moisture amounts are correlated to neutron probe readings and graphed.

Periodically, a licensed operator visits the field and lowers the neutron probe leads into each access tube. The readings are compared with the site's calibration curve to determine soil water content. The soil water content is then plotted on a graph to show water used since the last irrigation and when the next irrigation should be applied.

Neutron Probe Soil Water Content Curves



Reprinted from Irrigation Scheduling Services Program, Hamilton, MT (1987).

Oven Method

Also known as the gravimetric method, this is one of the most accurate methods for determining soil water content. It is used mainly to compare actual water content of the soil with the readings of a tensiometer, moisture block, or neutron probe. The oven method takes some work and time. An irrigator familiar with this method, however, can analyze 20 to 30 samples in about 1 1/2 hours using the microwave or 4 to 5 hours using the kitchen oven. The SCS can provide the steps and forms for this method.

DETERMINING APPLICATION TIME AND IRRIGATING

If the four variables discussed below are known, it's easy to calculate the hours required to add enough water to bring the root zone up to field capacity.

1. **Net irrigation** (in inches)—the amount required to bring the soil moisture up to field capacity.
   Note: The irrigation delivery system often dictates the amount of net irrigation. For instance, it may be possible to replace moisture only in the upper two feet of the soil profile with a pivot system during peak use periods. On the other hand, most border systems deliver plenty of water to fill the soil from critical level to field capacity.
2. **Irrigated area** (in square feet)
3. **Flow rate** (in gpm)—can be determined from pump tests or by measuring water at the delivery point (sprinkler heads, canal, dam).
4. **System efficiency** (in percent)—the amount of water that enters and stays in the root zone depends on a system's application efficiency. The following table shows estimated efficiencies.

Typical Irrigation System Application Efficiencies for Properly Designed and Well Managed and Maintained Systems

System Type	Application Efficiency (percent)
Side roll	65
Hand move	65
Periodic move gun or boom	50
Traveling gun	60
Center pivot	65
Graded border	50
Automated border (drop gate turnouts)	70
Level border (basin)	75
Graded furrow	50
Automated furrow (cablegation and surge)	70
Contour ditches	20

Adapted from "Feel and Appearance" Method of Soil Moisture Determination, Soil Conservation Service, Bozeman, MT.

The following formula translates the four variables to application period (set time). (The 96.3 constant converts the measurements to hours.)

$$\frac{\text{net irrigation (inches) x irrigated area (sq ft)}}{\text{flow rate (gpm) x 96.3 x system efficiency (\%)}} = \text{set time (hours)}$$

Steps for applying this formula to various irrigation systems are shown on the next few pages.

Side roll, hand move, end tow

1. Find the gallon-per-minute flow rate for the nozzles.
   - o Choose four operating sprinklers (the sprinklers should be from a fairly level lateral and 1/3 down the length of a lateral to estimate the average flow of each lateral.

- Hold one end of a short length of hose over the sprinkler head and put the other in a 5-gallon bucket.
- Use a stopwatch to estimate the time to fill the bucket.
- Repeat for the other three sprinklers.

2. Add the seconds and divide by 4 to get the average seconds per sprinkler to fill a bucket.
3. Divide the number 300 by average seconds to convert seconds to GPM per sprinkler:

$$\frac{300}{\text{AVERAGE SECONDS}} = \text{\_\_\_\_\_GPM/sprinkler}$$

Calculate the application rate:

$$\frac{\text{net irrigation x sprinkler spacing x lateral spacing}}{\text{nozzle flow (gpm) x 96.3 x efficiency}}$$

Example:
2.5 inches net irrigation
40 feet between sprinklers
60 feet between lateral positions
8 gpm per sprinkler
65% system efficiency

$$\frac{2.5 \text{ in. x } 40 \text{ x } 60}{8 \text{ gpm x } 96.3 \text{ x } .65} = \text{12-hour set}$$

Center Pivot System

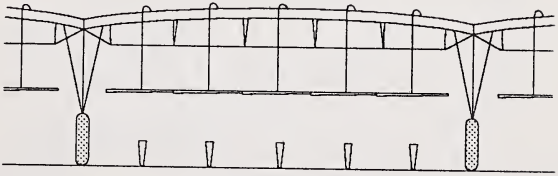
Example:
0.5 inches net irrigation per rotation
130-acre field (1 acre = 43,560 sq. ft.)
900 gpm system
65% system efficiency

$$\frac{0.5 \text{ in.} \times 130 \times 43560}{900 \text{ gpm} \times 96.3 \times .65} = 50\text{-hour rotation}$$

Verifying Center Pivot Application Rate

To physically check the net irrigation, use five rain gauges with stands. Set the gauges an equal distance apart in front of the pivot so that one span near the end of the pivot will cross over them. Let the span cross the gauges. Average the depth in the gauges to find net irrigation.

Placement of Gauges Under Pivot Sprinkler



Stationary Big Gun Sprinkler

Example:
2.5 in. net irrigation
78 gpm system
120 x 120 sprinkler spacing
50% system efficiency

$$\frac{2.5 \text{ in.} \times 120 \times 120}{78 \text{ gpm} \times 96.3 \times .50} = 10\text{-hour set}$$

Traveling Big Gun Sprinkler

For a traveling big gun, the formula changes (W is the width between travel lanes):

$$\frac{\text{gpm} \times 1.605 \times \text{efficiency}}{\text{net irrigation} \times W} = \text{travel speed}$$

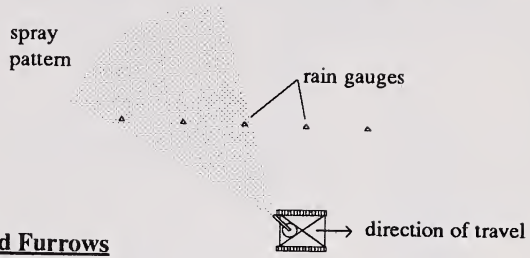
Example:
3.0 inches net irrigation
300 feet between travel lanes
400 gpm system
60% system efficiency

$$\frac{400 \text{ gpm} \times 1.605 \times .60}{3.0 \text{ in.} \times 300} = 0.4 \text{ feet/minute travel speed}$$

Verifying Traveling Big Gun Sprinkler Application Rate

Use five rain gauges. Set the gauges across the path of the sprinkler so they take a cross section through the middle one-third of the sprinkler. Let the sprinkler travel past the gauges. Average the depth in the gauges. This method for measuring application rate assumes there is little or no overlap in the middle one-third from adjacent travel paths.

Placement of Gauges under Traveling Big Gun



Graded Furrows

Example:
2.7 inches net irrigation
10 gpm flow
660-foot-long x 3-feet-wide furrows
50% system efficiency

$$\frac{2.7 \text{ in.} \times 3 \times 660}{10 \text{ gpm} \times 96.3 \times .50} = 11\text{-hour set}$$

Contour Ditches

Example:
1.5 inches net irrigation
800 gpm flow
40-acre field
20% system efficiency

$$\frac{1.5 \times 40 \times 43560}{800 \text{ gpm} \times 96.3 \times .20} = 7 \text{ 24-hour days}$$

NOTE: Weirs and flumes are common devices an irrigator can install to measure water delivery in open ditch irrigation. Publications describing their design and use are contained under More Information at the end of this section.

Calculating Flow Based on Set Time

The net irrigation amount from any set time can be calculated by plugging these four variables into a formula:

1. Application period (in hours)
2. Flow rate in gallons per minute (GPM)
3. Irrigated area (in square feet)
4. System efficiency (percent)

$$\text{Net irrigation} = \frac{\text{application period (hours)} \times \text{flow rate (gpm)} \times 96.3 \times \text{system efficiency}}{\text{irrigated area (square feet)}}$$

Example:

$$\frac{12 \text{ hours} \times 8 \text{ gpm} \times 96.3 \times .65}{40 \times 60 \text{ feet}} = 2.5 \text{ inches}$$

For a traveling big gun, the formula changes (W is the width between travel lanes).

Net irrigation for traveling big gun =

$$\frac{\text{gpm x 1.605 x system efficiency}}{\text{W x S}}$$

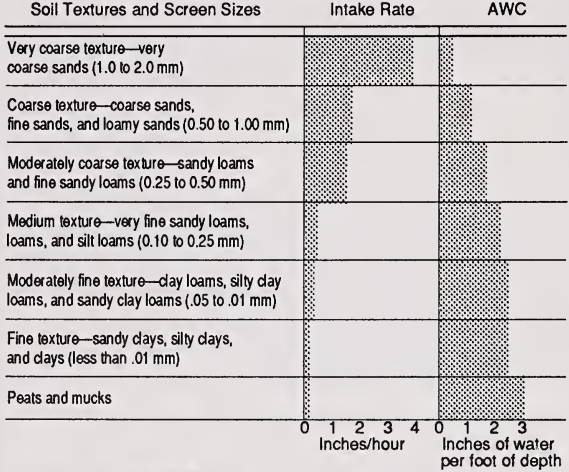
Example:

$$\frac{400 \times 1.605 \times .60}{300 \times 0.4 \text{ ft./min}} = 3 \text{ in.}$$

Intake Rates

An irrigation system that applies water at a rate that can be accepted by the soil minimizes runoff, waterlogging, fertilizer leaching, saline seep, and other yield-reducing problems. The following graph illustrates how soil texture influences intake rates and AWC.

Intake Rates and Available Water-Holding Capacities of Soils With Different Textures



Reprinted from Planning for an Irrigation System, American Association for Vocational Instructional Materials and USDA, Soil Conservation Service.

Generally, shallow sandy soils and shallow rooted crops require frequent irrigations that apply a lot of water in a short time. Deep fine textured soils and deep rooted crops require less frequent irrigations that apply lighter amounts of water but for a longer time.

Intake rates can vary between soil types, within the same soil type, from year to year, and even with the season. Factors that will increase or decrease intake rates are set forth below. The local Conservation District office can help to determine just how much influence these factors have on the intake rate of the soil.

Modifying Factors

Initial water content
Density
Compaction
Hardpan
Gravel or coarse sand layer near surface
Sediments in the irrigation water
Surface crusting
Soil erosion
Salts
Cracking
Tilth
Organic content
Vegetative cover
Ripping

The SCS has charts based on field tests showing intake rates for Montana soils.

MORE INFORMATION

BONNEVILLE POWER ADMINISTRATION
P.O. Box 3621
905 N.E. 11th
Portland, OR 97232
503-230-3000
- Energy and Water Conservation
- Motor Operation & Maintenance
- Electric Power Charges
- (info also available at local electric coop)

MONTANA COOPERATIVE EXTENSION SERVICE
Montana State University
Bozeman, MT 59715
406-994-3402
- Soil and Water Management
- Computer Irrigation Scheduling

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
Energy Division
1520 East Sixth
Helena, MT 59620
406-444-6697
- Irrigation Workshops
- Tractor Clinics
- Energy Conservation

MONTANA LOCAL CONSERVATION DISTRICTS
Directory available from: Conservation Division
DNRC
1520 East Sixth
Helena, MT 59620
406-444-6667
- Soil and Water Management
- On-Site Aid

PACIFIC NORTHWEST EXTENSION PUBLICATIONS
Oregon State University Extension Service
Agricultural Engineering
Corvallis, OR 97331-3906
503-754-4021
Soil & Water Management
Irrigation System Operation
Irrigation System Design

USDA SOIL CONSERVATION SERVICE
State Water Management Specialist
Federal Building, Room 443
10 East Babcock Street
Bozeman, MT 59715
406-587-6811
Soil and Water Management
Irrigation System Design

WESTERN AREA POWER ADMINISTRATION
P.O. Box 3402
Golden, CO 80401
303-231-1513
Energy Conservation in Pumping Plants

NORTHERN MONTANA COLLEGE
Ag/Mech Technical Department
Havre, Mt 59501
Jim Headlee: 406-265-4158
Greg Clouse: 406-265-4187
Farm Equipment Operation and Maintenance
Mechanical/Technical Aid

PUBLICATIONS

American Association for Vocational Instructional Materials in cooperation with U.S.D.A. Soil Conservation Services. *Planning for an Irrigation System*. Prepared by J. Howard Turner and Carl L. Anderson. Athens, GA, 1971.

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—. *Level-Basin Irrigation: A Method for Conserving Water and Labor*. Farmers' Bulletin Number 2261. Prepared by Leonard J. Erie and Allen R. Dedrick. Water Conservation Laboratory. Phoenix, AZ, 1979.

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SOIL TEXTURE SAMPLES

Date _____ **Field #** _____ **# Acres** _____

1. Probe each quarter section at six to ten representative locations, or probe each 20 acres. Unusual areas in the field such as wet spots, saline seeps, and rocky areas should be avoided or recorded separately.
2. Record on field diagram where samples were taken.
3. Note other factors such as high water table, hardpan, compacted layers, mineral layers, root penetration, tilth, and condition of the soil.

FIELD
DIAGRAM

	Accumulated Soil Layer Depth	Soil Texture Class	Series Name (if known)
Sample # __	0 to ___ ft.	_____	_____
	___ to ___ ft.	_____	_____
	___ to ___ ft.	_____	_____
	___ to ___ ft.	_____	_____
Sample # __	0 to ___ ft.	_____	_____
	___ to ___ ft.	_____	_____
	___ to ___ ft.	_____	_____
	___ to ___ ft.	_____	_____
Sample # __	0 to ___ ft.	_____	_____
	___ to ___ ft.	_____	_____
	___ to ___ ft.	_____	_____
	___ to ___ ft.	_____	_____

CALCULATING TOTAL AWC

Date _____ **Field #** _____ **# Acres** _____

Steps 1 and 2		Step 3	Step 4	
Layer Thickness (feet)	Soil Texture	AWC (inches/foot)	Adjust for Factors*	Net AWC (inches/foot)
_____	_____	_____ x	_____% =	_____
_____	_____	_____ x	_____% =	_____
_____	_____	_____ x	_____% =	_____
_____	_____	_____ x	_____% =	_____
_____	_____	_____ x	_____% =	_____

0-10 days 1 foot
__ft. x ____in./ft. AWC = ____in. (layer 1)
__ft. x ____in./ft. AWC = ____in. (layer 2)
total AWC = ____ in.

10-30 days: 2 feet
__ft. x ____in./ft. AWC = ____in. (layer 1)
__ft. x ____in./ft. AWC = ____in. (layer 2)
__ft. x ____in./ft. AWC = ____in. (layer 3)
total AWC = ____ in.

30-50 days: 3 feet
__ft. x ____in./ft. AWC = ____in. (layer 1)
__ft. x ____in./ft. AWC = ____in. (layer 2)
__ft. x ____in./ft. AWC = ____in. (layer 3)
__ft. x ____in./ft. AWC = ____in. (layer 4)
total AWC = ____ in.

50-90 days 4 feet
__ft. x ____in./ft. AWC = ____in. (layer 1)
__ft. x ____in./ft. AWC = ____in. (layer 2)
__ft. x ____in./ft. AWC = ____in. (layer 3)
__ft. x ____in./ft. AWC = ____in. (layer 4)
__ft. x ____in./ft. AWC = ____in. (layer 5)
total AWC = ____ in.

90+ days: 5 feet
__ft. x ____in./ft. AWC = ____in. (layer 1)
__ft. x ____in./ft. AWC = ____in. (layer 2)
__ft. x ____in./ft. AWC = ____in. (layer 3)
__ft. x ____in./ft. AWC = ____in. (layer 4)
__ft. x ____in./ft. AWC = ____in. (layer 5)
__ft. x ____in./ft. AWC = ____in. (layer 6)
total AWC = ____ in.

*Density, compaction, tilth, salts/sodium, organic matter are some of the factors that would decrease or increase AWC.

DETERMINING CRITICAL LEVEL AND DEPLETABLE WATER

DATE_____ FIELD #_____ # ACRES_____

CROP_____ EMERGENCE DATE_____

MAXIMUM ROOT DEPTH_____

Step 1		Step 2	Step 3	Step 4	Step 5
Days Post-Emergence	Root Depth	Stage of Growth	AWC per Root Depth	Critical Level	Depletable Amount per Root Depth
0 - 10 days	1 ft.		____in.	_____%	_____in.
10 - 30 days	2 ft.	Vegetative	____in.	_____%	_____in.
30 - 35 days	3 ft.		____in.	_____%	_____in.
35 - 50 days	3 ft.	Repro-	____in.	_____%	_____in.
50 - 90 days	4 ft.	ductive	____in.	_____%	_____in.
90 + days	5 ft.	Maturity	____in.	_____%	_____in.

CROP DAILY WATER USE - BY TEMPERATURE

DATE_____FIELD #_____# ACRES_____

CROP_____DEPLETABLE WATER_____

EMERGENCE DATE_____WEEKS POST-EMERGENCE____

Day	Temperature Low	High	Average	Average Daily Use Rate	Cumulative Water Use
WEEKS POST EMERGENCE_____					
WEEKS POST EMERGENCE_____					

Date of Last Irrigation _____

Scheduled Irrigation Date_____

EVAPORATION PAN

Worksheet for Determining Remaining Depletable Soil Water and Approximate Daily Water Use Rates

OBSERVER _____ CROP _____

LOCATION _____ PLANTING DATE _____

			Step 1		Step 2	Step 3	Step 4	Step 5	Step 6
Month/ Day	Days/Week Post-Emergence	Time	Pan Water Level (inches)	Change in Pan Water Level (inches)	Rain Gauge Reading x 0.75 (inches)	Total Evap. = Pan Loss Plus Effective Rainfall (inches)	Average Daily Crop Water Use (inches)	Adjust for Location = Daily Use x 0.65 (inches)	Crop Growth Stage Adjustment

EMERGENCE DATE _____

SOIL _____

INTAKE RATE _____

IRRIGATION APPLICATION
(Sprinkler only) _____

MAX. ROOTING DEPTH _____

Step 7	Step 8	Step 9		Step 10	
Average Net Daily Crop Water Use (inches)	Accumulated Soil Water Use (inches)	Maximum Depletable Water (inches)	Remaining Depletable Water (inches)	Estimate Irrigation Date	NOTES

FEEL AND APPEARANCE SOIL MOISTURE TESTING

Soil Sample Locations

FIELD #_____ **# ACRES**_____ **CROP**_____ **GROWTH STAGE**_____

FIELD DIAGRAM

CALCULATING SOIL WATER DEFICIT BY FEEL AND APPEARANCE

Figures in steps 1 and 2 are obtained from earlier calculations. Take soil samples and use the table on page 44 to determine the feel and appearance class. Apply the percentages to the AWC to estimate soil water deficit. Irrigation should be scheduled when the soil water deficit approaches the depletable water amount.

Step 1				Step 3	Step 4	Step 5	
Layer Thickness (feet)	Soil Texture	Net AWC (inches/foot)	AWC per layer to root depth (inches/foot)	Depth of Soil Sample (inches)	Feel and Appearance Class	Soil Water Deficit (percent)	Soil Water Deficit (inches/foot)

Step 2: Depletable water = ____ x ____ = ____

Total soil water deficit = _____

Schedule irrigation when soil water deficit approaches the critical level.

Energy Division
Montana Department of Natural
Resources and Conservation
1520 East Sixth
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EQUIPMENT MAINTENANCE

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EQUIPMENT MAINTENANCE

INTRODUCTION

The Montana Irrigators' Pocket Guide is a take-to-the field reference to help irrigators save energy and water. The Equipment Maintenance section contains a list for equipment maintenance and operation. Common measurements, conversions, and formulas are listed at the end of this section. Recommended pump installations are also illustrated.

Although proper design and installation are the first steps for an efficient irrigation system, it's the operation and maintenance that determine its success or failure. Therefore, the guide is not intended to help in the design or planning of new or replacement irrigation systems.

The maintenance and operation section is divided into three areas:

Shut-Down Maintenance: Maintenance that should be performed when shutting down an irrigation system for the season.

Start-Up Maintenance: Maintenance that should be performed prior to starting the irrigation season.

Operational Maintenance: Maintenance that should be performed on a regular basis during the operation of the pumping unit.

Spaces beside each maintenance item provide room for penciling in the maintenance date for three years.

NOTE: Instructions in owners' manuals should be followed if they differ from these.

SHUT-DOWN MAINTENANCE

CAUTION: Before beginning this procedure, disconnect the pump, or perform the service prior to draining the pump unit, or grease the pump packing to lubricate it before starting the engine.

ENGINE—Shutdown	Year 1	Year 2	Year 3

Engine Oil Change ☐ ☐ ☐

- o Run the engine until it reaches operating temperature.
- o Shut off the engine and drain the oil.
- o Change the filter.
- o Replace oil drain plug and make sure it's tight.
- o Add new oil.

IMPORTANT: Use only the oil recommended by the manufacturer. Tag each engine with a label identifying the proper oil.

- o Run the engine again for about two minutes to distribute the oil

Engine Oil Analysis

✔ Have a sample of used engine oil analyzed for contaminants, which will signal abnormal wear. Intervals between analyses will depend on the engine. Equipment dealers should know where oil can be analyzed. ☐ ☐ ☐

Engine Coolant

✔ If the coolant is an all-year type, ensure that the level and degree of protection are adequate. ☐ ☐ ☐

- ✔ If the coolant is water, drain and refill the cooling system with water, a rust inhibitor, and anti-freeze. ☐☐☐
- ✔ Check pH level using a pH test kit. ☐☐☐

Engine Fuel

- ✔ Drain all fuel from the tank and lines. If LP gas is used, drain vaporizer-regulator (drain both fuel and water lines). ☐☐☐
- ✔ Remove and clean or replace the fuel filter. ☐☐☐
- ✔ Check that oil filler cap, gas tank cap, and radiator cap are on tight and that gaskets aren't cracked. ☐☐☐
- ✔ If a gas engine, fill tank with non-alcohol based fuel. (Alcohol-based fuel can damage fuel lines during storage—but won't when being operated on a regular basis.) ☐☐☐ ☐☐☐
- ✔ If a diesel engine, fill tank with diesel and add fuel treatment additive to inhibit algae growth. ☐☐☐

Engine Lubrication

- ✔ Apply 5 to 7 pumps of new grease to any engine grease fittings including driveline, U-joints, and clutch. ☐☐☐

Engine Spark Plugs

- ✔ In engines that have them, pull, clean, re-gap, and replace spark plugs. ☐☐☐
- ✔ Fog gasoline engine as indicated below to coat internal parts with a film of oil: ☐☐☐
  - o With engine at idle speed, use

engine oil recommended by manufacturer and pour down carburetor until engine dies, or shut it off when it starts smoking.

Engine Distributor

- ✔ Remove the distributor cap and place a small amount of silicone lubricant (not oil) on the governor weights. ☐☐☐
- ✔ Replace the distributor cap and seal with weatherproof (duct tape or similar) tape where the cap joins the distributor housing. ☐☐☐

Engine Switches

- ✔ Spray a coat of electrical protection compound (similar to LPS 1 or a silicone spray) on any electrically-operated safety switches and on the ignition system to prevent corrosion. ☐☐☐

Engine Storage Preparation

- ✔ Seal all openings in the engine, including air cleaner inlet, exhaust outlet, and crankcase breather tube, with weatherproof tape. ☐☐☐
- ✔ Back off the tension on the "V"-belt pulley to prevent fan belt from bonding to the pulley. ☐☐☐
- ✔ Remove batteries, charge them, and store them in a cool (not freezing), dry place. ☐☐☐
- ✔ If engine is outside, cover with a water resistant tarp. ☐☐☐

NOTE: If engines have been properly winterized, they needn't be started during shutdown. However, if they are started, they

should be run until they reach partial operating temperature (when the temperature gauge needle begins to move upward).

CAUTION: If the pump cannot be disconnected from the engine, or if the unit is not equipped with a clutch, grease the pump packing to lubricate it before starting the engine.

MOTOR—Shutdown	Year 1	Year 2	Year 3

CAUTION: Before beginning this procedure, disconnect the pump, or perform the service prior to draining the pump unit, or grease the pump packing to lubricate it before starting the motor.

Motor Cleaning

✔ Use vacuum suction or dry filtered air pressure to remove dust and debris from moving parts of motor. (Don't exceed 50 pounds per square inch of air.) ☐ ☐ ☐

Motor Bearings:

✔ Grease bearings: ☐ ☐ ☐

- o Remove the bottom relief plug (usually located on the side near the bottom of the motor housing) and clean hardened grease out of passage.
- o Using a hand pump, fill housing with approved high temperature electric motor bearing grease (refer to the manufacturer's manual for API number of grease) until old grease is expelled.

CAUTION: If old grease is not expelled as new grease is pumped in, stop adding grease, and have your motor checked by a qualified repairman. Adding new grease

without old grease being removed could blow the seals and push grease into the motor.

- o Run motor until all surplus grease is thrown out through the bottom grease port (may require 5 to 10 minutes).
- o Shut off motor and use a screwdriver or similar device to remove a small amount of grease from the grease port to allow for grease expansion during full load operation.
- o Replace grease plug.

Motor Storage Preparation

✔ Cover motor to protect against rodents, insects, oil, and dust. To avoid condensation, use a breathable water-resistant tarp. ☐☐☐

CENTRIFUGAL PUMP—Shutdown (Refer to the figure on page 9.)

Year 1	Year 2	Year 3

Centrifugal Pump Piping

✔ Remove suction and discharge piping. Make sure drain valves are not plugged, and drain water from pump. ☐☐☐

Pump Packing Box

NOTE: Grease the packing box annually or the grease hardens and this task becomes very difficult.

✔ Grease packing box with a proper pump packing grease: ☐☐☐

o If packing box is equipped with a grease cup or a grease zerk apply a couple of pumps of packing grease to the packing box to force out remaining water and protect the packing.

o For a packing box without a grease cup or zerk, remove the last two packing rings (see page 8 to service packing) and discard. Pack packing grease into the packing box until full. Add two new rings and gently tighten the packing gland slightly to force the grease into the subsequent packing rings. Then loosen the gland.

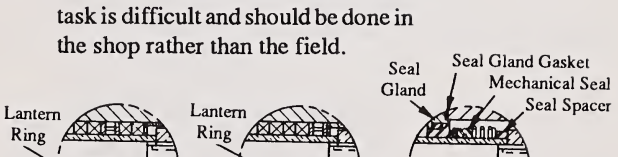
NOTE: If the packing box leaked excessively during the season, see the servicing instructions on page 8.

Centrifugal Pump Storage Preparation

- ✔ Cover any exposed metal, such as the shaft, with protective lubricant to eliminate corrosion. ☐☐☐
- ✔ Cover all oil- or grease-lubricated bearings with lubricant so moisture won't rust and pit them. ☐☐☐
- ✔ Loosen "V" belt or flat belt drive (if any). Back off tension between belts and pulley to prevent belt from bonding to pulley. ☐☐☐
- ✔ Remove diaphragm-type hand primer (if any) and store it in a building. ☐☐☐
- ✔ Remove discharge primer valve if equipped with rubber seat and store inside, or coat rubber part with rubber preservative. ☐☐☐
- ✔ Any rubber parts in a flexible coupling connecting the pump to the driver should also receive a coating of preservative. ☐☐☐
- ✔ Seal all openings, including suction, discharge, and primer, with weatherproof tape (duct tape or similar) against rodents and foreign material. ☐☐☐
- ✔ Store the pump in a clean, dry place, or cover with a tarp. ☐☐☐

SERVICING THE PUMP PACKING

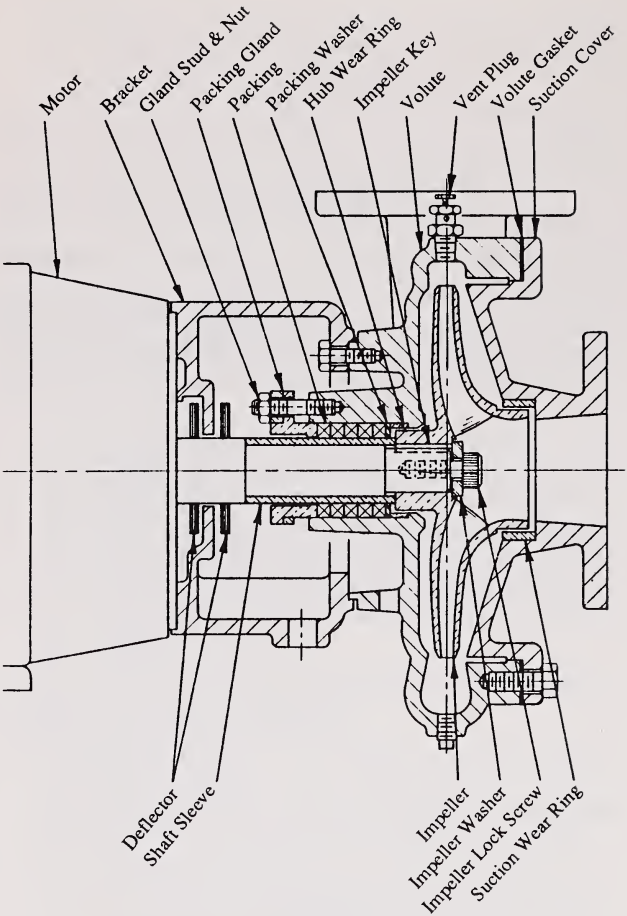
✔ Old packing should be replaced completely if leakage cannot be reduced by adding a new packing ring to the old packing, or if packing is burned (dried up and scorched). This task is difficult and should be done in the shop rather than the field.



PACKING WITH LANTERN SEAL | PACKING WITH LANTERN FLUSH | MECHANICAL SEAL

Packing Glands

- Remove packing box gland nut with a wrench, remove gland and packing.
- To remove packing, twist two packing pullers 180 degrees apart into the exposed packing ring. Pull each ring out of the packing box cavity until all are removed. The lantern ring has two holes 180 degrees apart and can be removed with the packing pullers.
- Replace shaft sleeve if worn or grooved; this usually requires pump disassembly. (Once the packing is burned and the shaft sleeve is scored, no amount of adjustment will maintain proper leakage for any length of time.)
- Before returning packing to box, insert the packing gland to make sure it enters freely to the gland's full depth. If it doesn't, clean out the fragments of old packing and other debris that may be obstructing it.
- Install new packing rings as far forward as can be reached. Install only the type and size of packing recommended by the manufacturer.



Typical Suction Cover Centrifugal Pump

Adapted from Cornell Pump Company Diagram 2000-10.

- Insert each ring separately. Push it squarely into the box and seat it firmly. A small amount of packing grease applied to the packing will make this job a little easier. Don't use sharp points to push packing into the box (use the packing gland, a wooden dowel, plier handle, fingers, or some other blunt object). Successive rings of packing should be installed so the joints are 120 degrees apart.
- Install lantern ring (if required) in proper position to the packing rings as shown on the parts page of your manual.
- Install packing gland so that it just begins to enter the stuffing box straight, so that the full packing is under uniform pressure.
- Seal with gland clip, stud and nut.
- If the packing box is equipped with a grease fitting, add a shot of grease.
- For a packing box without a grease cup or zerk, before inserting the last two packing rings, pack grease into the packing box until full. Add the last two rings and tighten the packing gland slightly to force the grease into the subsequent rings of packing. Then loosen the gland. (Also, a small amount of grease can be applied to each piece of packing as it is inserted.)

TURBINE PUMP—Shutdown Year 1 Year 2 Year 3

(Refer to the figure on page 12.)

Turbine Pump Packing

Maintain the packing on water-lubricated turbine pumps as directed on page 8 for centrifugal pump packing .

Turbine Pump Lower Bearings

✔ Grease bearings (if you have a turbine pump driven by a motor, this task is duplicated under motor maintenance): ☐ ☐ ☐

- Remove the bottom relief plug (usually located on the side near the bottom of the motor housing) and clean hardened grease out of passage.
- Using a hand pump, fill housing with approved high temperature electric motor bearing grease (refer to the manufacturer's manual for API number of grease) until old grease is expelled.

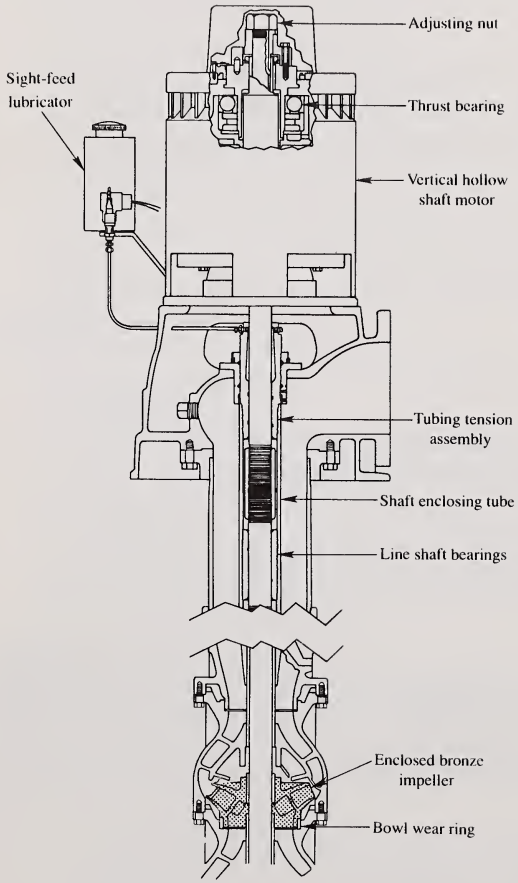
CAUTION: If old grease is not expelled as new grease is pumped in, stop adding grease, and have your motor checked by a qualified repairman. Adding new grease without old grease being removed could blow the seals and push grease into the motor.

- Run motor until all surplus grease is thrown out through the bottom grease port (may require 5 to 10 minutes).
- Shut off motor and use a screwdriver or similar device to remove a small amount of grease from the grease port to allow for grease expansion during full load operation.
- Replace grease plug.

Turbine Pump Upper Bearings

✔ Change the oil bath or reservoir for the upper bearings: ☐☐☐

- Drain the oil through the drain plug on the side of the pump.
- Replace the plug.
- Fill with approved turbine oil almost to the top of the sight glass so bearings are covered. Take care that excess oil doesn't get on or in the motor.



Oil Lubricated Turbine Pump

Adapted from Aurora Pump Company Bulletin 1130.

CONTROL PANEL—Shutdown

Year 1	Year 2	Year 3

CAUTION: After opening and before touching the control panel, use a voltmeter to BE SURE that the incoming power is disconnected or turned off.

- ✔ Clean out dust and dirt. ☐ ☐ ☐
- ✔ Replace, screen or putty any missing knock-out plugs and other holes in the starting switch box against rodents, insects, and dirt. Leave one small hole (3/16-inch diameter) unplugged on the bottom of the panel to allow moisture to drain. ☐ ☐ ☐
- ✔ Ensure that switches are in the off position. Lock the panel in the "off" position and remove the fuses to prevent accidental start-up and vandalism. Removing fuses will also prevent their corrosion. ☐ ☐ ☐
- ✔ Protect exposed control boxes against moisture and dust with a canvas cover. ☐ ☐ ☐

DISTRIBUTION SYSTEM—Shutdown

Ditches, Siphons, Cablegation, and Gated Pipe

- ✔ Clear ditches and repair cracks in concrete liners to prevent further damage from freezing. ☐ ☐ ☐
- ✔ Store siphon tubes, cablegation plugs (that move down the pipe), and system controllers under cover. ☐ ☐ ☐

✔ Store gated pipe with gasket end facing north to lessen damage from sunlight, and with gates closed and turned up to discourage rodents from gnawing the seals. ☐☐☐

Drip

✔ Treat the entire system with 40 ppm residual chlorine concentration for at least 4 hours, and completely flush the system. ☐☐☐

✔ Drain water from all pipelines. The system may have to be blown out lateral by lateral with an air compressor to effectively accomplish this. Don't exceed 15 to 20 pounds of air pressure, or the emitters will be blown off. Polyethylene pipes can stand some freezing without breaking, therefore, it isn't critical that all water be removed. In cases where remaining water may be a problem, however, add a gallon of non-toxic antifreeze (the type used in RVs) to the piping system and distribute it throughout with compressed air. More antifreeze may be necessary for larger systems. ☐☐☐

Center Pivot

✔ Park the pivot for the winter on level ground if possible, or slightly uphill from pivot. ☐☐☐

✔ Disconnect power to the center pivot. ☐☐☐

✔ Flush automatic drains so they are operating and free of sand. ☐☐☐

✔ Drain water from all pipelines and completely open valves to prevent freezing. ☐☐☐

✔ Inspect pipe for corrosion. If corrosion is found, consult the supplier for protection methods. ☐☐☐

- ✔ Grease all zerks liberally at least annually. ☐☐☐
- ✔ To prevent freeze damage in gearboxes, remove the drain plug to let any water out that has seeped in, then replenish with oil. Fill to 1/4 inch above the uppermost bearing, or to 1/4 inch of the top if it has an expansion chamber. The oil should be completely drained and refilled periodically; consult the manufacturer's recommendations for the oil type, weight and service schedule. ☐☐☐
- ✔ Booster pumps may have a mechanical seal in the packing box. If the seal wears out, replace it. ☐☐☐
- ✔ Check for proper tire inflation. ☐☐☐
- ✔ If possible, raise the tires and place boards under them, perpendicular to the line of travel, to allow movement as the system contracts and expands over the winter. ☐☐☐

Hand Moves, Side Rolls, Mainlines, and Laterals

- ✔ Flush automatic drains so they are operating and free of sand. ☐☐☐
- ✔ Drain water from all pipelines and completely open valves to prevent freezing. ☐☐☐
- ✔ Dismantle the pipelines into sections to prevent contraction damage in extremely cold weather. ☐☐☐
- ✔ Inspect pipe for corrosion. If any is found, consult the supplier for protection methods. ☐☐☐

- ✔ Store aluminum pipe on inclined racks well above the ground to permit drainage and air circulation. ☐☐☐
- ✔ If cattle will be in the same field, remove sprinkler heads and drains. ☐☐☐
- ✔ To prevent wind damage, secure side roll and other moving systems. Anchor securely to a post driven at every third or fourth wheel. ☐☐☐
- ✔ Avoid placing wheels in a ditch where expansion and contraction of the pipe can twist the wheels. ☐☐☐
- ✔ Avoid storing pipe near acids, caustic, or other chemical fumes or dusts, and avoid contact with animal waste. ☐☐☐
- ✔ Use plenty of grease on side roll chains annually. (A 5-gallon bucket of inexpensive grease and rubber gloves are all you need.) ☐☐☐
- ✔ On line movers, drain water that has seeped into hydraulic reservoirs and check the level of hydraulic fluid. ☐☐☐

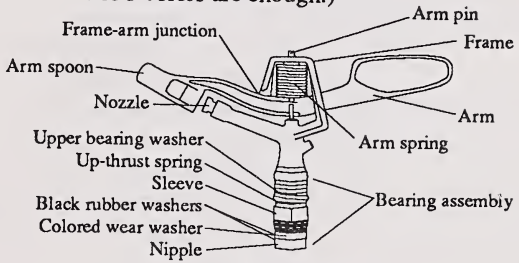
Gaskets and Couplers

- ✔ Remove gaskets, clean off silt, sand, or other debris, and store in a dry place. It's ideal to place them in a plastic garbage bag and sprinkle them with talcum powder to prevent cracking. ☐☐☐
- ✔ After the gaskets have been removed, clean couplers with water to remove foreign matter. ☐☐☐

Sprinkler Heads

✔ Remove a few 2- or 3-year-old sprinkler heads (depending on the amount of silt or minerals in the water, operating time, and other wear-causing variables). If some show wear, remove all sprinkler heads of the same age and check for wear. ☐☐☐

- o Use a box-end wrench to take apart sprinkler heads to avoid damage from open-end or pipe wrenches.
- o Because sprinkler manufacturers use different washer combinations, or different washers for the same model of sprinkler head depending on its use, take a sprinkler head along when ordering parts. Replacement parts from the original manufacturer fit better and last longer.
- o When reinstalling the sprinkler head, wrap the threads with Teflon plumber's tape. Petroleum-based pipe-dope compounds can cause early deterioration of the lower bearing rubber washers.
- o When installing sprinkler heads, spray a dab of paint on the new or repaired heads, (avoid getting over-spray on rubber or moving parts) and spray that same color on the shop wall and note the year. Use a different color for each year. (Since sprinkler heads last 1 to 5 years, depending on sediment in the water, 4 or 5 colors are enough.)



Sprinkler Head

Adapted from Maintaining Impact Sprinklers A304. Cooperative Extension Service, Oregon State University, Corvallis, OR.

- o Do not lubricate sprinkler heads for either storage or operation.

Sprinkler Bearing Assembly

✔ Check the lower bearing wear washer (often colored) and the one or two black washers. The lower bearing washers usually wear first. Replacing them delays wear in other parts of the sprinkler. ☐☐☐

- o Compare the wear washer against a new one for thickness and replace if noticeably thinner.
- o Replace the black washers when the wear washer is replaced.
- o Compare black washers against a new one for softness. If they are not as flexible, replace them.
- o Some old style sprinkler heads use a T-ring for the wearing surface. Replace the ring if it is noticeably thinner than a new one. To seat the T-ring, place it and the bearing washer on the nipple. Place the nipple in the sleeve and tap the end of the nipple.

NOTE: If most of the bearing parts are very worn, the entire bearing assembly may need to be replaced.

✔ Replace the upper bearing washer if it is noticeably thinner than a new one. ☐☐☐

✔ Replace the up-thrust spring if it is compressed so that it is shorter than a new one. If you keep the old spring, turn it upside down before replacing it. ☐☐☐

Sprinkler Arms

✔ Replace the arm spring if it is nicked where it passes through frame and arm. ☐☐☐

- ✔ Replace the arm pin if it is noticeably worn where it passes through the arm. ☐☐☐
- ✔ If the old arm is loose on the new pin compared to the fit of a new arm, have the sleeve rebuilt or replace it. ☐☐☐
- ✔ Replace the oscillating arm if it is damaged. If the angle of water-contact of the jet with the arm is not correct, it will change the turning characteristics of the sprinkler. ☐☐☐
- ✔ Inspect the spray head sprinkler diffuser for wear or other damage. ☐☐☐

NOTE: If you replace the arm or pin, lay the assembled sprinkler on a flat metal surface with the bearing toward you and the arm spoon to the right. Tap the frame-arm junction (right of the pin) to mate the two surfaces. Then tap the spoon and repeat until the arm makes contact with the metal surface from the frame to the end of the spoon. Some fine tuning may be necessary.

Sprinkler Springs

- ✔ Replace broken or damaged springs. Weak springs should also be replaced because they will cause improper spray patterns and can result in reduced production. ☐☐☐
  - o Check for spring wear by comparing an old spring to a new one. Replace the up-thrust spring if it is shorter than a new one.
  - o Springs of stainless steel wear longer than those of regular steel.
  - o The tension on the new spring must be set properly. Use a new sprinkler head for comparison. Hold the new sprinkler horizontal and hang a piece of wire

with a hook on the end on the arm; add nuts or washers to the hook until the arm starts to move. Hang this weight on the repaired sprinkler and adjust the tension until the weight just begins to move the arm. After two or three times, it will be easy to estimate the tension without using the weight.

Sprinkler Nozzles

Just a tiny bit of nozzle wear (a few thousands of an inch) can cause a big increase in sprinkler output and seriously decrease the system's efficiency.

✔ Remove the nozzle and clean out the interior. ☐☐☐

✔ Check the nozzle for wear using a numbered drill index with bits measured in thousandths or use a new high speed drill bit. If a drill bit is used, get a new nozzle to check alongside the worn nozzle so the amount of wear can be approximated. ☐☐☐

- o Insert the index into the nozzle opening and compare the size to that printed on the nozzle.
- o Or, insert the shank (smooth end) of the drill bit into the nozzle opening. The fit should be snug. If you can wobble the bit sideways even slightly, the nozzle is worn.

Sprinkler nozzles should be replaced when the energy cost due to a worn nozzle is greater than the replacement cost. Follow these steps to help determine that point.

Step 1. Once the amount of nozzle wear is estimated from the drill-bit check, locate the nozzle diameter on the left side of the table; follow the row across to the appropriate amount of wear column.

Increased Flow for Worn Nozzles Operating at 60 psi

Nozzle Diameter (inches)	Design Flow (gpm)	Nozzle Wear Over Original Size (in inches)					
		0.001	0.002	0.003	0.004	0.005	0.006
		Increased Flow in Gallons Per Minute					
1/8 (0.125)	3.50	0.06	0.11	0.17	0.23	0.29	0.34
9/64 (0.141)	4.43	0.06	0.13	0.19	0.26	0.32	0.39
5/32 (0.156)	5.48	0.07	0.14	0.21	0.28	0.36	0.43
11/64 (0.172)	6.62	0.08	0.16	0.23	0.31	0.39	0.47
3/16 (0.188)	7.88	0.08	0.17	0.25	0.34	0.43	0.51
13/64 (0.203)	9.25	0.09	0.18	0.28	0.37	0.46	0.56
7/32 (0.219)	10.73	0.10	0.20	0.30	0.40	0.50	0.60
15/64 (0.234)	12.32	0.11	0.21	0.32	0.42	0.53	0.64
1/4 (0.250)	14.02	0.11	0.23	0.34	0.45	0.57	0.68
17/64 (0.266)	15.82	0.12	0.24	0.36	0.48	0.60	0.72
9/32 (0.281)	17.74	0.13	0.25	0.38	0.51	0.64	0.77

Source: Sprinkler System Requirements. Jim Worstell. Idaho Power Company.

Step 2. Use the following formula to tailor the increased flow to your operating pressure, if different than 60 psi:

$$\sqrt{\text{your psi}/60\text{ psi}} \times \text{excess flow}$$

Example: Your nozzle size is 15/64 and wear is 0.004. From the table, increased flow at 60 psi is 0.42. If your psi is 40:

$$\sqrt{40\text{ psi}/60\text{ psi}} \times 0.42 = \sqrt{0.67} \times 0.42 = 0.82 \times 0.42$$
$$= 0.34\text{ gpm increased flow}$$

Step 3. Jot down the following for the irrigation system:

Nozzle size _____ inches
Nozzle wear _____ inches
Sprinkler operating pressure _____ psi
Excess flow due to wear (Step 2) _____ gpm
Nozzle replacement cost (parts & labor) $_____
Pumping plant efficiency (PPE) _____ percent
Electricity cost $_____ kWh
Total dynamic head (TDH) _____ feet
Hours of annual operation _____

NOTE: The publication Saving Energy on Montana Farms and Ranches, available free from DNRC, has instructions for finding TDH and estimating PPE.

Step 4. Use the following formula to determine if the excess flow per nozzle warrants replacement:

$$\frac{\text{(nozzle cost + labor cost) x PPE x 5308}}{\text{Electricity cost per kWh x head x operating hours}}$$

Example: Nozzle size 15/64 inches
Nozzle wear .004 inches
Operating pressure 40 psi
Excess flow due to wear (Step 2) 0.34 gpm
Nozzle replacement cost (parts & labor) $0.65
Pumping plant efficiency (PPE) 58 percent
Electricity cost 0.042 kWh
Total dynamic head (TDH) 112 feet
Hours of annual operation 1500

$$\frac{\$0.65 \times 0.58 \times 5308}{\$0.042 \times 112 \times 1500} = 0.28 \text{ gpm}$$

The excess flow at which energy costs exceed replacement costs is 0.28 gpm. The excess flow for the nozzles in the example is 0.34 gpm. Therefore, the nozzles should be replaced.

NOTE: Always replace a nozzle with one of the same size and model. Pivot systems have different sized nozzles. The supplier should furnish a computer printout of nozzle sizes for the system.

START-UP MAINTENANCE

CAUTION: If the pump cannot be disconnected from the engine or motor, or if the unit is not equipped with a clutch, grease the pump packing to lubricate it before starting the engine or motor.

NOTE: Instructions in owner's manuals should be followed if they differ from these.

ENGINE—Startup	Year 1	Year 2	Year 3
Engine General			
# Remove the tape on all engine openings and the distributor cap, and tighten belts.	☐	☐	☐
Engine Air Cleaner			
# If oil bath air cleaner is used, clean and refill the filter bath and reassemble the air cleaner. (See Operating Maintenance, page 36 for maintenance of regular air filters.)	☐	☐	☐
Engine Electrical System			
# If a magneto is used, inspect breaker points for wear and gap, and lubricate rotor.	☐	☐	☐

Charge batteries to correct specific gravity and connect them. ☐☐☐
Clean all connecting terminals; cover with protectors. ☐☐☐
Check all terminals and electrical connections for tightness and corrosion, and spray with corrosion inhibiter (NOT grease). ☐☐☐

Engine Lubrication

Lubricate all engine accessories such as the driveshaft, U-joints, and clutch throwout bearing. ☐☐☐
Turn on fuel tank shut-off valve. ☐☐☐
Replace the fuel filter. ☐☐☐

Engine Oil

If the engine has not been protected during shutdown, change the crankcase oil. ☐☐☐
    - o Start engine and bring slowly up to operating temperature.
    - o Shut off the engine and drain the oil.
    - o Replace oil drain plug and make sure it's tight.
    - o Add new oil.

    IMPORTANT: Use only the oil recommended by the manufacturer. Tag each engine with a label identifying the proper oil.

    - o Run the engine again for about 2 minutes to distribute the oil.

Engine Switches

Follow manufacturers' directions to check safety switches including overtemperature switch, loss-of-prime switch, and low oil pressure switch. ☐☐☐

Engine Final Checks

		Year 1	Year 2	Year 3
#	Start and run the engine for 10 minutes, then turn it off.	☐	☐	☐
#	Check oil and coolant levels.	☐	☐	☐
#	Check engine and pump for any leaks caused by drying gaskets.	☐	☐	☐

MOTOR—Startup	Year 1	Year 2	Year 3

Motor General

#	Remove the tape on all openings, and clean out rodents, insects, or debris.	☐	☐	☐
#	Use vacuum suction or dry filtered air pressure to remove dust and debris from moving parts of motor. (Don't exceed 50 pounds per square inch of air.)	☐	☐	☐
#	Check that air intake is free of weeds and trash.	☐	☐	☐
#	Locate the motor drain hole on the base or support for the base, and clean it out so water won't be trapped and held directly under the air intake. Even if windings are protected from moisture, minerals in the water can attach to the windings and cause early failure.	☐	☐	☐

Motor Electrical System

CAUTION: Before this check, be sure power is off.

#	Remove motor electrical connection hub.	☐	☐	☐

- o Check electrical connections from meter loop to motor for corrosion and clean if necessary. Aluminum wiring is especially susceptible to oxidizing. Coat the wiring and connectors with an antioxidant.

- o Check electrical connections from meter loop to motor for tightness. The extremes of winter temperatures can cause electrical connections (especially in aluminum wire) to expand and contract at different rates, loosening connectors that were tight in the fall. Retape if necessary.
- o Replace overheated connections or wires with new material. Poor electrical contact can cause low voltage and overheating.
- o Inspect insulation of windings. A special solvent may be sprayed directly on oil-soaked windings to remove dirt, grease, or oil.

Replace hub. ☐☐☐

Motor Bearings

NOTE: Lubrication instructions in owner's manuals should be followed if they differ from these.

Change the grease again to remove any accumulated moisture: ☐☐☐

- o Remove the bottom relief plug and clean hardened grease out of passageway.
- o Using a hand pump, fill housing with approved high temperature electric motor bearing grease (refer to the manufacturer's manual for API number of grease) until old grease is expelled.

CAUTION: If old grease is not expelled as new grease is pumped in, stop adding grease, and have your motor checked by a qualified repairman. Adding new grease without old grease being removed could blow the seals and push grease into the motor.

- o Run motor until all surplus grease is thrown out through the bottom grease port (may require 5 to 10 minutes).

- o Shut off motor and use a screwdriver or similar device to remove a small amount of grease from the grease port to allow for grease expansion during full load operation.
- o Replace grease plug.

Motor Oil

Change oil in reduced voltage starters. Be sure to clean and flush oil pan before refilling. ☐☐☐

Switches

Check all safety switches according to manufacturers' directions. ☐☐☐

Final Checks

Before applying power, operate all moving parts on the motor and pump by hand. ☐☐☐

Check for proper rotation of motor and pump. The pump shaft should turn in the direction of the arrow on the casing. (As viewed from the motor end, the rotation is usually clockwise.) ☐☐☐

CONTROL PANEL—Startup Year 1 Year 2 Year 3

CAUTION: After opening the control panel but before touching the controls, use a voltmeter to BE SURE that the incoming power is disconnected or turned off.

Control Panel Exterior

Clear tree branches or other physical obstructions from overhead lines. ☐☐☐

BE SURE that the service panel is properly grounded, independently of pumping plant. ☐☐☐

Check that service head grommets are in place and in good condition. ☐☐☐

Check that lightning arrestors are properly installed on the meter and motor side of buss and breaker. ☐☐☐

Control Panel Interior

Clean out debris, rodents, and insects. ☐☐☐

Replace fuses after checking to see that they aren't blown. Never use oversized fuses. ☐☐☐

Operate disconnect switch slowly to check for alignment of blades and clips. ☐☐☐

Open and close the switch several times to clean oxide from contact points. (Any time the switch has been left open, operate it several times before leaving it closed. Copper oxide can form in a few hours and result in poor contact and overheating.) ☐☐☐

Clean contacts of all dust and dirt. Clean copper contacts with very fine sandpaper or a fine file. Replace badly pitted or burned contacts. Never file silver or silver-plated contacts. Leave contacts clean and dry so dust won't collect. ☐☐☐

If easily accessible, check magnetic starter switch contact points. ☐☐☐

☐☐☐ Have your electrician or pump maintenance person do a Megger check on the control panel, motor, conduits, and other electrical connections. (The Megger device applies a small amount of voltage to an electrical component and measures the electrical resistance.) A Megger test can also detect potentially harmful moisture in windings.

NOTE: Corrosion can cause poor contact, poor grounding, direct or high resistance shorts.

☐☐☐ Shade the service panel to cool thermal breakers.

CENTRIFUGAL PUMP—Startup	Year 1	Year 2	Year 3
Centrifugal Pump General			
# In a frame pump, replace grease with proper weight of bearing lubricant.	☐	☐	☐
# Clean the drain hole on the underside of the pump.	☐	☐	☐
# Thoroughly clean suction and discharge piping and connections.	☐	☐	☐
Centrifugal Pump Reassembly			
# Use new gaskets and pipe-dope and reconnect the piping to the pump. Using a gasket in a coupling that it was not made for is the most common cause of leaky gaskets. Take the make of the coupling and the model number to your dealer. Quality gaskets will last longer.	☐	☐	☐

Re-install the primer and priming valve. ☐☐☐

Centrifugal Pump Starting

Hand crank to ensure that the pump shaft turns freely and is free of foreign objects. Application of power could break the impeller if it's rusted to the case. ☐☐☐

Prime the pump. ☐☐☐

Start the pump with the packing gland loose so there will be initial leakage. Tighten the packing gland only enough to draw the necessary vacuum for priming. If the packing has dried out, it may have to be greased before the pump will prime. ☐☐☐

Tighten the gland nuts slightly and evenly at 15 or 20 minute intervals so leakage is reduced to about 8 to 10 drops per minute or until the water leaking from the box is cool. **DON'T STOP LEAKAGE ENTIRELY.** ☐☐☐

Check the engine and pump for leaks caused by drying gaskets.

TURBINE PUMP—Startup	**Year 1**	**Year 2**	**Year 3**

Turbine Pump Well

Check the static level and drawdown in the well. A deeper pump setting might be required. ☐☐☐

Turbine Pump Lower Bearings

Re-grease bearings to remove any moisture accumulated during shutdown: ☐☐☐

- o Remove the bottom relief plug (usually located on the side of the motor and near the bottom of the housing) and clean hardened grease out of passage.
- o Using a hand pump, fill housing full of approved high temperature electric motor bearing grease (refer to the manufacturer's manual for API number of grease) until old grease is expelled.

CAUTION: If old grease is not expelled as new grease is pumped in, stop adding grease, and have your motor checked by a qualified repairman. Adding new grease without old grease being removed could blow the seals and push grease into the motor.

- o Run motor until all surplus grease is thrown out through the grease relief port (may require 5 to 10 minutes).
- o Shut off motor and use a screwdriver or similar device to remove a small amount of grease from the grease port to allow for grease expansion during full load operation.
- o Replace grease plug.

Turbine Pump Upper Bearings

Change the oil bath or reservoir for ☐☐☐ the upper bearings:

- o Drain the oil through the drain plug on the side of the pump.
- o Replace the plug.
- o Fill with approved turbine oil to the proper level. Take care that excess oil doesn't get on or in the motor.

Short-Coupled Turbine Pump Shaft Adjustment

Adjust the head shaft nut: ☐☐☐

- o Remove top motor cover and take out the set screw.
- o Remove, clean, oil, and replace the key stock.

- o Loosen the head shaft adjusting nut (it has a left-hand thread) so the shaft and bowls are resting on the bottom. Tighten the head shaft adjusting nut two turns which will raise the shaft and bowl assembly enough to allow for proper clearance.
- o You should be able to turn the shaft by hand once it's raised. If you can't, turn the head shaft adjusting nut one-half turn and try to turn it by hand again.
- o If you are unable to turn the shaft by hand, and you have raised the shaft 5 or more turns of the nut, remove the pump and disassemble and inspect for damage or debris.
- o Replace the set screw and motor cover.

On oil-lubricated pumps, fill the oil reservoir and start the oil flowing to the pump one hour before starting the pump. Check to see that the oil tube is filled before running the pump. Adjust the oiler to about 10 drops per minute. ☐☐☐

On water-lubricated pumps, maintain the packing the same as the centrifugal pump—see page 30. ☐☐☐

Deep Well Turbine Pump Shaft Adjustment

Shaft adjustment needs to be more precise for deep well turbines. Shaft stretch needs to be considered. Refer to the manufacturer's instructions. ☐☐☐

On oil lubricated pumps, start lubricating the shaft at least a day before starting the pump, or until the line shaft and column are full of oil and the oil begins to run out at the top near the stretch assembly. Deep well turbine pumps need about 10 drops of ☐☐☐

oil per minute. Check the manufacturer's instructions to be sure of the requirement. (Oil will drip slower at night when it cools down.)

Adjust and maintain packing on water-lubricated turbine the same as the packing on a centrifugal pump—see page 30.

DISTRIBUTION SYSTEM—Startup	Year 1	Year 2	Year 3
Ditches			
# Clean ditches of mud and weeds.	☐	☐	☐
Drip System			
# Check for rodent and mechanical damage.	☐	☐	☐
Center Pivot System			
# Clean pipe of animal nests.	☐	☐	☐
# Treat corroded pipe according to supplier's recommendations.	☐	☐	☐
# Check the gear box lubricant annually to ensure it is filled to proper level. Every two to five years, change the gear box lubricant. Follow the manufacturer's recommendations for type and weight.	☐	☐	☐
# Disconnect the electrical power and check that the motor lead connections are tight and not burned or corroded.	☐	☐	☐
# Check and lubricate all valves according to manufacturer's instructions.	☐	☐	☐

#	Grease the center pivot swivel with one full tube of grease.	☐	☐	☐
#	Grease the driveline if equipped with grease-type U-joints, and check for excessive wear.	☐	☐	☐
#	Seal tower boxes to keep water out if they show signs of moisture.	☐	☐	☐
#	Check for proper tire inflation. Uneven tire pressure is hard on gear boxes. Fill tires (22-25 psi for 11.9 tires, 16-18 psi for 14.9 tires), and tighten the lug nuts.	☐	☐	☐
#	Flush the system thoroughly (30 minutes) with drains and plugs removed to prevent plugging nozzles and pressure regulators.	☐	☐	☐
#	Replace drains and end plugs.	☐	☐	☐

DISTRIBUTION SYSTEM—Startup	Year 1	Year 2	Year 3

Hand Moves, Side Rolls, Mainlines, Laterals

CAUTION: KEEP PIPE AWAY FROM POWER LINES WHEN RAISING FOR CLEANING

#	Clean pipe of animal nests.	☐	☐	☐
#	Inspect for bent or flattened piping, split seams, and punctures. Use a slightly tapered wooden plug of proper diameter to round out damaged ends.	☐	☐	☐
#	Treat corroded pipe.	☐	☐	☐
#	Reassemble all couplers, gaskets, risers, and sprinkler heads.	☐	☐	☐
#	Check and lubricate all valves according to manufacturer's instructions.	☐	☐	☐

☐☐☐ Elevate aluminum mainline off the ground with short boards or old tires to allow air circulation and prevent electrolysis.

☐☐☐ Lay out pipe as straight as possible to minimize friction loss through couplers.

☐☐☐ Install air release valves and vacuum relief as needed on high points of line.

☐☐☐ Set pressure relief valve at 10 psi above normal operating pressure, or at pressure specified to protect pipe.

☐☐☐ Tap exposed steel pipe with a rubber hammer before startup to release rust.

☐☐☐ Flush the system thoroughly (30 minutes) with drains and plugs removed to prevent plugging nozzles and pressure regulators with any dirt, rust, or other foreign material that may be in the system.

☐☐☐ Replace drains and end plugs.

NOTE: Before the crop is up, aerial photographs of your system operating on bare soil can quickly identify plugged nozzles, bad pressure regulators, broken impact sprinklers, and other problems.

OPERATING MAINTENANCE

System—Precheck

☐ Before each irrigation, make sure engine or motor and pump are secure and tight. Mounting and other types of bolts often vibrate loose. Check that intake and

discharge pipe are firmly supported in the area near the pump.

ENGINE—Operating

- ☐ Check coolant, oil levels, fuel, and fan belts before each irrigation. If coolant or oil is down, check lines for leakage.
- ☐ On diesel engines, check injectors and fuel lines for leaks.
- ☐ Override safety switches that protect against low water pressure, loss of oil pressure, and overheating.
- ☐ Start the engine.
- ☐ After engine has reached operating speed, activate the safety switches.
- ☐ If the air induction system is equipped with a pre-screener, brush blockage off screen periodically.
- ☐ Change the air cleaner only when the service indicator signals that it's time to change it.
  - o Turn off the engine before changing an air filter.
  - o Wipe the outside of the cover and housing with a damp cloth and remove the cover.
  - o Inspect the cover; if it is dented or warped, replace it.
  - o Remove the filter. Use extreme care to prevent dirt from falling into the intake duct.
  - o Use a clean, damp cloth to wipe inside of filter housing.
  - o Install new air filter. Always replace air filter with a new one. Cleaning it will distort the filter and allow more dirt to enter.
  - o Replace cover.

MOTOR—Operating

- ☐ Clean grass or debris from air ventilation openings on motors to allow a full flow of cooling air.

☐ Inspect electrical conduit to ensure that it stays dry and the connections are tight.

☐ Lubricate the motor according to manufacturer's instructions. Intervals between lubrication will vary with speed, power, load, ambient temperatures, exposure to contamination and moisture, seasonal or continuous operation and other factors.

- o Electric motors shouldn't be greased daily. Bearings can be ruined by either over- or under-greasing.
- o When grease is added, the grease and fittings must be absolutely clean, and the old grease must be flushed out of the bearing housing.
- o To prevent over-greasing, lubricate when the motor is <u>not</u> running. Allow for grease expansion by running with vent plug open. See the instructions on page 5 for greasing motor bearings.

Recommended Regreasing Periods for Motors

	Horsepower Range		
<u>Type of Service</u>	<u>1 1/2 - 7 1/2</u>	<u>10 - 40</u>	<u>50 - 150</u>
Normal Duty (8-hour day)	8 months	6 months	4 months
Heavy Duty (24-hour day)	4 months	3 months	2 months

PUMP—Operating

☐ Clean trash screening device (if any) and screens on suction pipe.

☐ Check the engine and pump for leaks caused by dry gaskets.

☐ On oil-lubricated pumps, check the oil level, turn on oil, and lubricate turbine shafts before pump is started.

☐ Check oil level periodically during operation.

- ☐ Prelubricate line shaft bearings of water-lubricated turbine pumps.
- ☐ Check packing. A pump with sleeve and packing in good condition and properly adjusted shouldn't require constant re-adjustment, but should be checked daily. If the proper leakage isn't running through the packing box, the packing will become overheated and dry out, eventually burning and scoring the shaft sleeve.
- ☐ Open the discharge valve if the pump is equipped with a priming valve. Otherwise, leave the discharge valve closed. Start the pump and then slowly open the discharge valve.
- ☐ To eliminate water hammer and prevent high amperage draw on demand meters, open the discharge valve slowly to fill mainline.
  CAUTION: Don't let the pump run more than 2 minutes with the valve closed.
- ☐ To stop, slowly depressurize the system. Don't just turn off the motor or engine. Rather, decrease the pump discharge from the pipeline by closing valves slowly before power is turned off.
  Use a non-slam check valve to prevent backspin of the pump or running engines in reverse direction.

DISTRIBUTION SYSTEM—Operating

Drip

- ☐ Check emitters for correct flow. Take precise measurements at least twice each year by catching the flow from a number of emitters in a calibrated cylinder for exactly 1 minute.
- ☐ Watch for leaks, rodent damage, and mechanical damage.
- ☐ Flush sediment from the ends of the laterals periodically.
- ☐ Replace cartridge filter or backflush sand filter periodically.

Center Pivot, Hand Moves, Side Rolls, Mainlines, and Laterals

- ☐ See that risers are in place and not tipped.
- ☐ Check pipe, valves, drains, and risers for plugging from grass and other debris.
- ☐ Flush sediment from the ends of the laterals periodically.

Sprinkler Heads

- ☐ Verify that sprinkler heads are in place and rotating.
- ☐ Check that nozzles aren't plugged. Unplug nozzles with something softer than the material they are made of. Do not hammer a head to dislodge a plug. For other problems such as a bent arm, broken spring, or broken arm pin, replace the head with one of your extras.
- ☐ On center pivot systems, check each pressure regulator at a sprinkler head. If it leaks out the side airhole during operation, replace it.

EQUIPMENT TROUBLESHOOTING

This section identifies symptoms and lists possible causes under Suction, System, and Pump. Ninety-five percent of the time, suction problems are the cause.

Suction Problems	Symptoms										
	Pump does not deliver water	Insufficient capacity (gpm)	Pump loses prime after starting	Insufficient pressure	Pump requires excessive power	Packing box leaks excessively	Packing box has short life	Pump vibrates or is noisy	Bearings have short life	Pump overheats and seizes
Pump not primed Check connections between the pump and primer. On a hand primer, if grass or other debris is lodged in the check valve, air is being put back into the pump at every stroke. A vacuum gauge installed on the pump or suction line will indicate if the primer is pulling a vacuum or just moving air through the pump.	•									•
Insufficiently submerged suction pipe inlet	•	•	•							
Pump or suction pipe not completely filled with water 1) The suction line may be plugged or partially collapsed. 2) High spots can cause air pockets in the suction line; re-do the suction setup to eliminate. 3) The discharge head must be equal to the suction head for the pump to work. A pump located on the edge of a river bank or ditch where the discharge line goes immediately	•	•	•					•		

Suction Problems	Pump does not deliver water	Insufficient capacity (gpm)	Pump loses prime after starting	Insufficient pressure	Pump requires excessive power	Packing box leaks excessively	Packing box has short life	Pump vibrates or is noisy	Bearings have short life	Pump overheats and seizes
downhill from the pump will initially have less discharge head than suction head. Install a valve on the discharge side to increase the discharge head on the pump until the line is full. 4) Check the lift capability of the pump. If the water level has dropped, the pump must be moved closer to the water or the suction piping size increased (to reduce friction losses) until the unit is operating within the maximum suction lift for which it was designed. Suction lifts (that is, the vertical distance from water surface to pump impeller) of more than 15 to 20 feet are too high for efficient operation. The closer the pump can be located to the source of supply, the better. Too long or too small suction lines have the same effect as a high suction lift due to increased friction when the water passes through the line.										
Insufficient Net Positive Suction Head (NPSH) A centrifugal pump doesn't pull water from a source; it only pumps water that is delivered to it. Delivery, in most cases, occurs as a result of the weight of the earth's atmosphere which forces the water to rise in a suction pipe from which air has been removed by the primer pump.	•	•						•		•

Suction Problems

As elevation, water temperature, and pipe friction increase, the ability of the pump to create a perfect vacuum decreases, and the height of the column of water that can be forced drops. The maximum column of water that can be lifted in a pipe under a given set of these conditions is known as Net Positive Suction Head or NPSH. Generally, the maximum vertical distance a pump can be set above the water is 12 to 15 feet for the NPSH available at about 3,000 feet elevation.

Insufficient NPSH often occurs on irrigation pumps when first starting up. During system pressurization, the pump has little back pressure. Therefore, it pumps more water than the system is designed for and can exceed the NPSH. The pump can go into a condition of cavitation and become very noisy. This usually exists for a very few minutes until the line fills. Cavitation can generally be prevented by installing a butterfly or gate valve on the pump discharge. Slowly open the valve during start-up so the pump is always operating against the design pressure, until the system is filled.

	Symptoms									
	Pump does not deliver water	Insufficient capacity (gpm)	Pump loses prime after starting	Insufficient pressure	Pump requires excessive power	Packing box leaks excessively	Packing box has short life	Pump vibrates or is noisy	Bearings have short life	Pump overheats and seizes
Suction line, strainer, or water-seal pipe plugged		•					•			

Suction Problems

	Symptoms									
	Pump does not deliver water	Insufficient capacity (gpm)	Pump loses prime after starting	Insufficient pressure	Pump requires excessive power	Packing box leaks excessively	Packing box has short life	Pump vibrates or is noisy	Bearings have short life	Pump overheats and seizes
Air leaks into suction line The most common source of air leaks is the threaded connection of the suction line. Coat these connections with pipe cement or white lead and draw them tight. Another common source of leaks is in cracks around welds. Gaskets sometimes shrink and admit air. Tighten the flanges or connections, or replace the gaskets.		•	•							
Air leaks into pump through packing box Screw tight all drain and fill plugs in the pump case. (NOTE: use a pipe thread compound on all pipe threads.) Check for cracks or holes in the pump case. Packing may be dried and hardened, especially if the pump has been out of service. Add grease if it has a grease cup and tighten packing gland, or replace the old packing with new. (After pump is running, be sure to loosen packing gland to ensure proper leakage.)		•	•							

Suction Problems	Symptoms										
	Pump does not deliver water	Insufficient capacity (gpm)	Pump loses prime after starting	Insufficient pressure	Pump requires excessive power	Packing box leaks excessively	Packing box has short life	Pump vibrates or is noisy	Bearings have short life	Pump overheats and seizes
Excessive amount of air or gas in the water Water in the sump where it enters the suction pipe should be relatively calm.		•	•	•						
Foot valve too small, insufficiently submerged, or partially clogged			•					•		
Pump not primed Check for air leaks on discharge valves. Sand or other debris lodged between the rubber flap and the valve seat will prevent the check valve from sealing and forming a tight joint. See if the rubber face is cracked or chipped and not seating. Many all-metal gate type valves will never seal properly to allow a vacuum. Replace the gate valve or install a priming check valve. A properly sized air relief device should be installed on every irrigation pump; it is required when a buried mainline is used.	•	•								

System Problems	Symptoms									
	Pump does not deliver water	Insufficient capacity (gpm)	Pump loses prime after starting	Insufficient pressure	Pump requires excessive power	Packing box leaks excessively	Packing box has short life	Pump vibrates or is noisy	Bearings have short life	Pump overheats and seizes
Speed too low On internal combustion engines, the governor may need adjusting. On electric motors, the power company or an irrigation service should check the wiring and voltage. If the speed cannot be increased, a larger pipeline may have to be installed to reduce friction and increase the capacity of the pump.	•	•		•						
Parallel operation of pumps unsuitable	•	•		•						•
Total system head higher than pump design head ***Turbine Pump Only** Check the design with the Soil Conservation Service or an irrigation system designer to determine the best solution.	•	•		•	•*					

System Problems	Symptoms									
	Pump does not deliver water	Insufficient capacity (gpm)	Pump loses prime after starting	Insufficient pressure	Pump requires excessive power	Packing box leaks excessively	Packing box has short life	Pump vibrates or is noisy	Bearings have short life	Pump overheats and seizes
Wrong direction of rotation See the start-up instructions that came with the pump. On 3-phase motors, swap any two power leads to change rotation.	•			•	•					
Speed too high Check the rating of the pump and reduce speed to the pump rating.					•					
Total system head lower than pump design head Check the design with the SCS or an irrigation system designer to determine the best solution.					•					
Operation at very low capacity (gpm) ***Turbine Pump Only**					•*			•		•

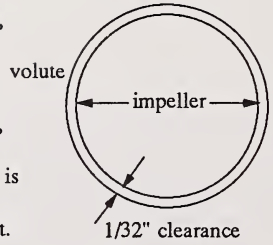
Pump Problems	Symptoms										
	Pump does not deliver water	Insufficient capacity (gpm)	Pump loses prime after starting	Insufficient pressure	Pump requires excessive power	Packing box leaks excessively	Packing box has short life	Pump vibrates or is noisy	Bearings have short life	Pump overheats and seizes
Rotary shaft seals may leak air Check for an improperly greased or worn rotary shaft seal by running the pump and squirting oil on the shaft just outside the seal. Oil drawn into the seal indicates a leak. Filling the seal with grease may eliminate the difficulty. If the parts are worn, repairs may be required. Keep the seal full of the proper grade of grease to avoid trouble.	•									
Foreign matter in impeller	•	•			•			•		
Wearing rings worn				•	•					
Impeller damaged Checking for an impeller clogged with foreign matter or damaged, or for worn wearing rings on the volute case, will take some work. Use care in dismantling the pump.				•				•		

Pump Problems

The following directions are simplified. If possible, follow the manufacturer's manual.

- o Remove suction cover or volute case.
- o Remove debris from impeller and volute.
- o Check wear at impeller eye and vanes. If worn, repair or replace the impeller.
- o Remachine or replace wearing ring if clearance is greater than 1/32 inch per side.
- o Replace suction cover or volute; use new gasket.

Checking Impeller



	Symptoms										
	Pump does not deliver water	Insufficient capacity (gpm)	Pump loses prime after starting	Insufficient pressure	Pump requires excessive power	Packing box leaks excessively	Packing box has short life	Pump vibrates or is noisy	Bearings have short life	Pump overheats and seizes
Defective casing gasket permitting internal leakage				•						
Misalignment of pump and driving unit					•	•	•	•	•	•
Bent shaft					•	•	•	•	•	
Rotating part rubbing on stationary part Check to see if cooling fins or the armature are rubbing on the motor housing.					•			•	•	•

Pump Problems	Symptoms									
	Pump does not deliver water	Insufficient capacity (gpm)	Pump loses prime after starting	Insufficient pressure	Pump requires excessive power	Packing box leaks excessively	Packing box has short life	Pump vibrates or is noisy	Bearings have short life	Pump overheats and seizes
Packing gland too tight resulting in no water flow to lubricate packing					•		•			
Packing worn, improperly installed, or incorrect for operating conditions See the pump instruction manual and packing instructions in the Maintenance section earlier.					•	•	•			
Cooling water not getting to water-cooled packing boxes Debris may be obstructing the water flow, or the packing gland may be so tight that no water is flowing to lubricate packing.						•	•			
Packing forced into pump interior Check for excessive clearance at bottom of stuffing box between shaft and casing						•	•			

Pump Problems	Symptoms									
	Pump does not deliver water	Insufficient capacity (gpm)	Pump loses prime after starting	Insufficient pressure	Pump requires excessive power	Packing box leaks excessively	Packing box has short life	Pump vibrates or is noisy	Bearings have short life	Pump overheats and seizes
Shaft or shaft sleeves worn or scored at the packing Check for dirt, silt, or sand in the water.						•	•			
Shaft running off center Check for worn bearings or misalignment.						•	•	•	•	•
Impeller or rotor (electric motors) out of balance						•	•	•	•	•
Bearings worn							•	•	•	•
Foundation not rigid								•		

Pump Problems	Symptoms									
	Pump does not deliver water	Insufficient capacity (gpm)	Pump loses prime after starting	Insufficient pressure	Pump requires excessive power	Packing box leaks excessively	Packing box has short life	Pump vibrates or is noisy	Bearings have short life	Pump overheats and seizes
Pipe not supported Pipe not properly supported will stress the connection between the pipe and pump.								•	•	
Excessive bearing temperature Excessive grease or oil in anti-friction bearing housing or lack of cooling. Inspect for signs of excessive grease around internal motor housing. Remove relief plug and check condition of grease. Regrease if necessary.								•	•	
Condensation of atmospheric moisture in the bearing housing Check for excessive cooling of water-cooled bearing.								•	•	
Lack of lubrication or improper lubrication Check lubrication notes in earlier Maintenance section.								•	•	

Pump Problems	Symptoms									
	Pump does not deliver water	Insufficient capacity (gpm)	Pump loses prime after starting	Insufficient pressure	Pump requires excessive power	Packing box leaks excessively	Packing box has short life	Pump vibrates or is noisy	Bearings have short life	Pump overheats and seizes
Scoring or rusting of bearings Cracked or broken seals may allow dirt or water to get into the housing. Replace the seals.								•	•	
Improper installation of anti-friction bearings Check for damage during assembly, incorrect assembly of stacked bearings, and use of unmatched bearings as a pair. Replace the bearings or have them checked and replaced by a qualified pump repairman.								•	•	
Excessive thrust Check for a mechanical failure inside the pump or for failure of the hydraulic balancing device, if it has one. Disconnect the external balance line to see if it is clear of obstructions.								•	•	•

Flow Rate Conversion

Cubic Ft. per Second	Gallons per Minute	Gallons per 24 hours	Montana Miner's Inches	Acre Ft. per 24 hours	Acre In. per 24 hours
0.00223	1	1,440	0.09	0.004	0.05
0.025	11.2	16,128	1	0.05	0.6
0.50	224.4	323,136	20	1	11.9
1.00	448.8	646,272	40	2	23.8
1.50	673.2	969,408	60	3	35.7
2.00	897.6	1.29 M	80	4	47.6
2.23	1000.0	1.44 M	89	4.5	54.0
2.50	1122.0	1.62 M	100	5	59.5
3.00	1346.4	1.94 M	120	6	71.4
3.50	1570.8	2.26 M	140	7	83.3
4.00	1795.2		160	8	95.2
4.50	2019.6		180	9	107.1
5.00	2244.0		200	10	119.0
5.50	2468.4		220	11	130.9
6.00	2692.8		240	12	142.8
6.50	2917.2		260	13	154.7
7.00	3141.6		280	14	166.6
7.50	3366.0		300	15	178.5
8.00	3590.4		320	16	190.4
8.50	3814.8		340	17	202.3
9.00	4039.2		360	18	214.2
9.50	4263.6		380	19	226.1
10.00	4488.0		400	20	238.0

1 cfs is a volume 1-foot wide, 1-foot long, and 1-foot high passing a given point every second.
1 acre inch covers one acre of land one inch deep; 1 acre foot covers one acre of land one foot deep.
1 acre inch per 24-hour day requires 18.7 gpm continuous flow.

$$\text{gpm} = \text{cfs} \times 448.8$$
$$\text{cfs} = \text{gpm} \times .00223$$

$$\text{Gross application of water in acre inches per acre} = \frac{\text{GPM x hours}}{450 \times \text{number of acres}}$$

Volume Conversions

Gallons	Pounds (water)	Cubic Feet	Acre Inches	Acre Feet
1	8.33	0.1337		
7.48	62.4	1		
27,154		3,630	1	1/12
325,850		43,560	12	1
1 million				3.07

Length Conversions

Inches	Link	Feet	Yards	Rod/Pole	Chain	Furlong	Mile
7.92	1						
12		1					
36		3	1				
	25	16.5	5.5	1			
	100	66	22	4	1		
				40	10	1	
		2640	880	160	40	4	0.5
		5280	1760	320	80	8	1

Area Conversions

Square Feet	Square Yards	Square Rods	Square Chains	Acre
43,560	4,840	160	10	1

square feet x .000023 = acres
square yards x .00021 = acres
square rods x .0062 = acres
square chains x 0.10 = acres

Pressure Conversions

Feet of Head	Inches of Mercury	Pounds per Sq. Inch	Atmosphere
33.93	29.92	14.7	1
1.00	0.88	0.4335	0.0295
2.31		1	

Total dynamic head (TDH) (in feet) = lift + pipe friction loss + pressure head + velocity head

Pressure head (in feet) = psi (from gauge) x 2.31

Energy Conversions

Btu/hour	Horsepower	kilowatts
3,413	1.341	1
2,545	1	0.746

$$\text{Brake horsepower} = \frac{\text{GPM x Head (in feet)}}{\text{3960 x Efficiency of Pump}}$$

$$\text{Water horsepower} = \frac{\text{GPM x TDH (in feet)}}{\text{3960}}$$

Electrical Consumption

Electrical consumption is measured in units of 1,000 watts (kilowatts) used every hour. The number of watts being consumed is the product of the operating voltage and the level of current flowing to the load, and for three-phase, multiplied by 1.73. The number of watts are divided by 1,000 to obtain kilowatts. The symbols for these units are:

E = voltage
I = current (or amps)
W = watts
kWh = kilowatt-hours

The formula to calculate kilowatt-hours is:

Single Phase

$W = E \times I \times \text{hours}$ $\quad kWh = W/1000$

Three Phase

$W = 1.73 \times E \times I \times \text{hours}$ $\quad kWh = W/1000$

Water Velocity Conversions

Velocity in feet per second (fps) = $\frac{.409 \times \text{flow (gpm)}}{\text{pipe diameter (inches) squared}}$

Example: 300 gpm 6-inch pipe

$$\frac{.409 \times 300}{36} = 3.4 \text{ fps}$$

Recommended Maximum Flow Rate for Different Pipe Sizes

Pipe dia. (inches)	2	3	4	5	6	8	10	12	16
Flow rate (gpm)	50	110	200	310	440	780	1225	1760	3140

Note: For maximum efficiency, velocity should be kept at 5 fps or less. Energy can be saved by increasing pipe size, reducing flow rate, and changing pipe type.

Head Loss Comparison
(feet lost per 100 feet of pipe)

	4-inch Pipe				6-inch pipe				8-inch pipe				10-inch pipe				12-inch pipe			
GPM	S	A	C	P	S	A	C	P	S	A	C	P	S	A	C	P	S	A	C	P
100	1.25	.81	.69	.55	.17	.11	.09	.08												
150	3.00	1.73	1.43	1.18	.36	.23	.20	.16	.09	.06	.05									
200	4.39	3.65	2.73	2.01	.62	.42	.35	.28	.15	.10	.08	.07	.05							
300	9.47	6.35	5.31	4.27	1.32	.92	.72	.60	.32	.21	.17	.14	.11	.07	.06	.05	.05			
350		8.32	6.93	5.43	1.73	1.16	.95	.79	.43	.28	.23	.19	.14	.09	.08	.06	.06			
400		10.74	9.01	7.39	2.31	1.50	1.25	1.02	.55	.37	.30	.25	.18	.12	.10	.09	.08	.05		
450			11.89	9.24	2.77	1.85	1.52	1.27	.69	.45	.38	.32	.23	.15	.13	.11	.10	.06	.05	
500				11.55	3.47	2.31	1.85	1.55	.83	.55	.46	.39	.28	.18	.15	.13	.12	.08	.06	.05
550					4.11	2.66	2.24	1.85	0.99	.66	.55	.46	.33	.22	.18	.16	.14	.09	.08	.06
600					4.85	3.19	2.66	2.19	1.18	.79	.67	.54	.39	.25	.22	.18	.17	.11	.09	.07
650					5.54	3.70	3.12	2.54	1.39	.90	.79	.63	.46	.30	.25	.21	.19	.13	.11	.09
700					6.47	4.27	3.58	2.89	1.62	1.04	.88	.72	.53	.35	.29	.24	.22	.15	.12	.10
750					7.39	4.85	4.04	3.35	1.80	1.16	.99	.82	.60	.39	.33	.28	.25	.16	.14	.11
800					8.32	5.54	4.62	3.70	2.02	1.27	1.11	.89	.68	.42	.38	.31	.28	.18	.16	.13
850					9.24	6.12	5.08	4.16	2.31	1.50	1.25	1.03	.76	.51	.42	.35	.32	.21	.18	.15
900					10.16	6.93	5.66	4.62	2.54	1.67	1.39	1.16	.84	.55	.46	.39	.35	.23	.19	.16

S = Steel Pipe A = Aluminum Pipe C = Cement Asbestos Pipe P = Plastic Pipe

GPM	4-inch Pipe				6-inch pipe				8-inch pipe				10-inch pipe				12-inch pipe			
	S	A	C	P	S	A	C	P	S	A	C	P	S	A	C	P	S	A	C	P
950					11.55	7.39	6.24	5.20	2.82	1.85	1.54	1.35	.95	.61	.51	.43	.39	.25	.21	.18
1000						8.32	6.93	5.66	3.07	2.02	1.67	1.40	1.03	.65	.55	.48	.43	.28	.23	.19
1050						9.01	7.62	6.24	3.35	2.25	1.85	1.50	1.12	.74	.61	.51	.46	.31	.25	.21
1100						9.93	8.32	6.93	3.70	2.54	2.01	1.65	1.25	.81	.67	.56	.51	.33	.28	.23
1200						11.55	9.70	8.09	4.39	2.72	2.43	1.96	1.46	.95	.80	.66	.60	.39	.33	.27
1300							11.55	9.24	5.08	3.44	2.77	2.28	1.69	1.11	.92	.76	.71	.46	.39	.31
1400								10.51	5.89	3.81	3.23	2.59	1.96	1.25	1.06	.88	.81	.52	.44	.37
1500									6.58	4.39	3.58	2.93	2.19	1.47	1.21	1.00	.92	.60	.51	.42
1600									7.39	4.97	4.04	3.29	2.54	1.60	1.39	1.12	1.04	.67	.58	.46
1700									8.32	5.54	4.62	3.70	2.77	1.85	1.55	1.27	1.16	.76	.65	.52
1800									9.24	6.12	5.08	4.13	3.10	2.08	1.73	1.39	1.29	.84	.72	.57
1900									10.16	6.81	5.54	4.62	3.47	2.31	1.85	1.55	1.46	.95	.79	.65
2000									11.32	7.39	6.24	5.08	3.80	2.54	2.08	1.70	1.59	1.04	.87	.69

S = Steel Pipe A = Aluminum Pipe C = Cement Asbestos Pipe P = Plastic Pipe

Example: A system with a flow of 500 gpm through six-inch steel pipe is losing 3.47 feet of head per 100 feet of pipe.

Adapted from Montana Irrigation Manual, USDA Soil Conservation Service, Bozeman, MT.

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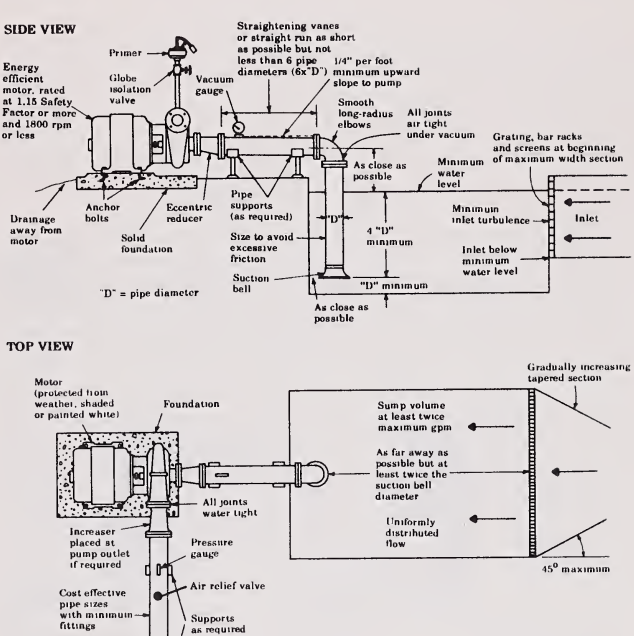
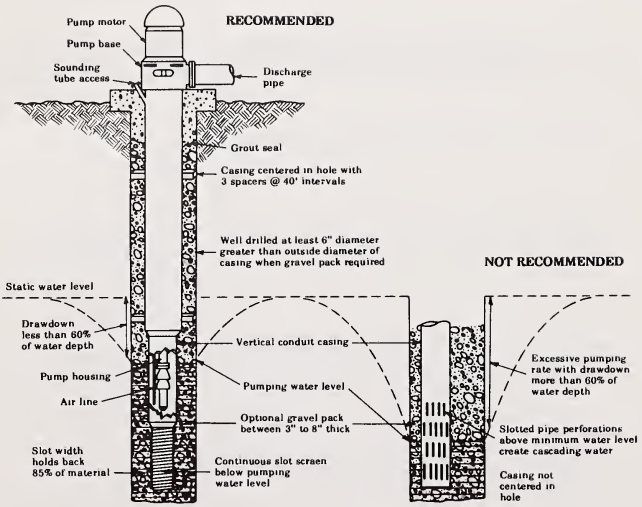
RECOMMENDED PUMP INSTALLATION



Adapted from Energy Efficient Pumping Standards. Utah Power & Light Company

DEEP WELL CONSTRUCTION



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SPRINKLER SYSTEM MAINTENANCE

Field No._____Beginning Date_____Ending Date_____

Maintenance Schedule

Date pump start-up_____Amps_____Beginning PSI_____
Test Date_____Amps_____Test Date_____
Test Date_____Amps_____Test Date_____
Test Date_____Amps_____Test Date_____
Test Date_____Amps_____Test Date_____

Scheduled Replacement Dates

	Sys 1	Sys 2	Sys 3	Sys 4	Sys 5
Nozzles					
Heads					
Levelers					
Gauges					
Gaskets					
Chains					
Motors					
Oil					
Filter					
Drains					
Hose					
Screens					

PUMP:
Installation Date_____
Dealer_____
Mfgr._____
Model_____
Serial #_____
Repair Date_____
By_____

SYSTEM:
Installation Date_____
Dealer_____
Mfgr._____
Model_____
Serial #_____
Special Equip_____
By_____

PUMP:
Installation Date_____
Dealer_____
Mfgr._____
Model_____
Serial #_____
Repair Date_____
By_____

SYSTEM:
Installation Date_____
Dealer_____
Mfgr._____
Model_____
Serial #_____
Special Equip_____
By_____

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Equipment Maintenance

The Montana Irrigator's Pocket Guide

Energy Division • Department of Natural Resources and Conservation